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A QUIET REVOLUTION IN SPACE SYSTEMS

Associate Professor I. Michael Ross, Department of Aeronautics and Astronautics
Associate Professor Wei Kang, Department of Mathematics
Associate Professor Fariba Fahroo, Department of Mathematics

In recent years, the innovative idea of distributing the functionality of large satellites among smaller, cooperative satellites has been seriously considered for numerous space missions – military and civilian – such as high-resolution, synthetic-aperture imaging using clusters of satellites orbiting in formation. In formation "flying,"[1] groups of micro-satellites are operated cooperatively to act as a sparse aperture with an effective baseline larger than that which can be achieved by a single, large satellite (see Figure 1). Satellite clusters offer many advantages over large, lumbering, flexible spacecraft such as:

- Significantly larger effective apertures,
- Configurable apertures that can be banded for a specific mission and re-configured for another one,
- Fault tolerance, in that a failure of a single satellite is not detrimental to the mission; and full mission capability can be achieved by simply replacing the old one with a "stand-by" spacecraft,
- Aggressive maneuverability, as small spacecraft can be rapidly maneuvered cooperatively for retargeting without incurring "flexibility problems."

To achieve these and other objectives, one must have the capability to launch a "swarm of spacecraft" in a cost-effective manner and "on demand." Militarily, the demand may arise from tactical needs to support unforeseen theaters as evident from recent world events. In civilian usage, the launch on-demand philosophy is referred to as airline-like operations. Once in orbit, the demands are even greater. On-orbit demands come from the need to maneuver satellites to various orbital positions, swarm reconfigurations and revisits over a theater. A key enabling technology for launching and maneuvering

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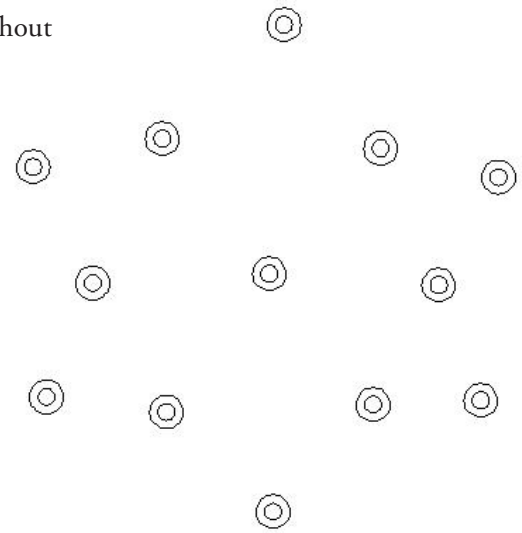

Figure 1. Schematic of a Satellite Swarm in Formation: Such configurations can achieve significantly larger effective apertures than a single, large, bulky spacecraft. The aperture may also be reconfigured by repositioning some or all of the satellites.

IN THIS ISSUE

NPS RESEARCH

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FEATURED PROJECT

A QUIET REVOLUTION IN SPACE SYSTEMS, *continued from page 1*

these swarms is robust optimal guidance and control. It turns out that the mathematical fundamentals for launch vehicle guidance, orbit transfer, formation design, formation control, and many other areas are the same: optimal control of nonlinear dynamical systems. Significant breakthroughs have been achieved at NPS in this area by **Associate Professors Wei Kang** and **Fariba Fahroo** of the Department of Mathematics, and **Associate Professor I. Michael Ross** of the Department of Aeronautics and Astronautics. Their research work currently provides a vast variety of research topics to students pursuing both Masters and Ph.D. degrees in Space Systems (including Astronautics), Mathematics, Electrical Engineering, and Mechanical Engineering.

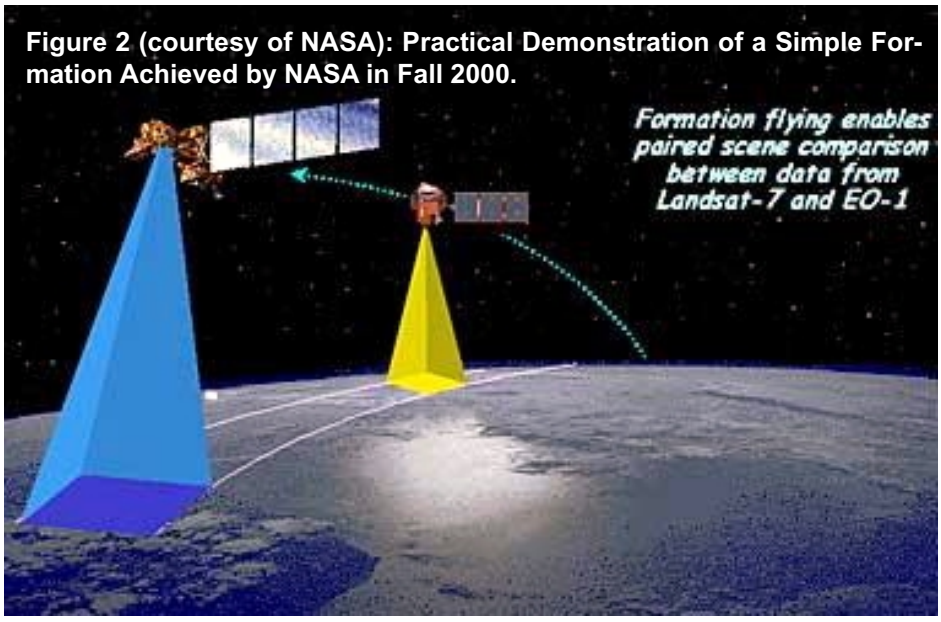

Figure 2 (courtesy of NASA): Practical Demonstration of a Simple Formation Achieved by NASA in Fall 2000.

Some of the ideas on sparse apertures by formation design and control have already been demonstrated (see Figure 2). EO-1 launched in November of 2000 carries instruments for high-resolution images. The satellite was designed to fly in a formation with another NASA satellite called Landsat-7. The EO-1 satellite flies 60 seconds (450 kilometers) behind

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About the INVESTIGATORS

I. Michael Ross is an Associate Professor in the Department of Aeronautics and Astronautics at the Naval Postgraduate School (NPS). He also holds a joint appointment with the Space Systems Academic Group. Dr. Ross received his Ph.D. in Aerospace Engineering from Penn State.

Dr. Ross is the 14th recipient of the Carl E. and Jessie W. Menneken Award, the highest honor awarded by the NPS for Excellence in Scientific Research. His current research focus is on developing pseudospectral theory and techniques for the real-time computation of optimal controls for nonlinear and nonsmooth dynamical systems. He is the lead software architect for DIDO, the object-oriented reusable software for rapid dynamic optimization. The software and its variants have been used extensively at the Charles Stark Draper Laboratory, the former MIT Instrumentation Laboratory (where Ross spent two years as a Visiting Associate Professor). It is also being used at a number of universities and laboratories across the country. DIDO has been used to solve a wide variety of complex optimal control problems arising in orbital dynamics, launch vehicle design, rigid body control, flexible body control, formation keeping and configuration design, missile guidance and many other areas. Professor Ross is also the co-developer of ACAPS, a MATLAB code used at the California Institute of Technology Jet Propulsion Laboratory for the preliminary design of interplanetary aeroassisted maneuvers. It has been used for the preliminary design of several Mars missions. For about three years at NPS, he served as the Project Lead on PANSAT, a small experimental communications satellite currently in low-Earth-orbit. He has also served in leadership roles at the national level, chairing and organizing several conferences and commit-

I. Michael Ross

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A QUIET REVOLUTION IN SPACE SYSTEMS, *continued from page 2*

Landsat-7. This separation makes it possible for EO-1 to repeat the observation of the leading satellite over the same ground area through the same atmosphere region, which is one of the numerous advantages of formation flying. Onboard EO-1 is an autonomous controller that is capable of real-time planning and executing satellite orbit maneuvers based on sensor information.

Professors Kang, Fahroo, Ross and NPS students are developing new concepts, software tools and the supporting theory for enabling the design, control and optimization of vastly more complex formation swarms. In an Air Force

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About the INVESTIGATORS, *continued from page 2*

tees in AIAA and AAS including the prestigious AIAA Mechanics and Control of Flight Award Committee. An Associate Fellow of AIAA, he is the founding Book Review Editor for the *Journal of Guidance Control and Dynamics*. He has over 55 journal and conference publications in the open literature.

Wei Kang is an Associate Professor in the Department of Mathematics. He received his Ph.D in mathematics from the University of California at Davis in 1991 and the M.S. and B.S. in mathematics from Nankai University of China in 1985 and 1982, respectively. From 1991 to 1994, Dr. Kang was a Visiting Assistant Professor of System Science and Mathematics at Washington University in St. Louis. Dr. Kang joined the Naval Postgraduate School in 1994. Dr. Kang's interest of research is nonlinear control theory with engineering applications, including bifurcation control, H-infinity control, formation control, and their applications in aircraft, engine compressors, mobile robots, and multi-satellite systems. Dr. Kang has an extensive publication list in SIAM, IEEE, and AIAA journals. He is an associate editor of *IEEE Transactions on Automatic Control*. He serves on the Program Committee of the IEEE Conference on Decision and Control of 2002. Dr. Kang was the recipient of the Best Paper Award of the 6th International Conference on Control, Automation, Robotics and Vision, Singapore, December 6-8, 2000. Dr. Kang is the Principal Investigator on several DoD and industrial research projects.

Wei Kang

Fariba Fahroo is an Associate Professor in the Department of Mathematics. She received her A.B. degree in Applied Mathematics and Physics from the University of California at Berkeley, M.A. degree in Applied Mathematics from the University of Wisconsin at Madison, and her Ph.D. in Applied Mathematics from Brown University. She joined the Naval Postgraduate School in 1992 as a Visiting Assistant Professor and is currently an Associate Professor of Mathematics. Her areas of interest are partial differential equations, control theory, optimization, numerical analysis, and numerical trajectory optimization. She is an active interdisciplinary researcher and has collaborated with faculty at the University of Southern California, Worcester Polytechnic Institute and North Carolina State University on such topics as acoustic-structure control, noise reduction, control of flexible structures, smart structures and mathematical control theory. At NPS, her interdisciplinary research activities have been with Professor Yutaka Kanayama from the Department of Computer Science and Professor Ross from the Department of Aeronautics and Astronautics.

Fariba Fahroo

Dr. Fahroo has over 40 research publications and her research efforts have earned her an NPS Recognition Award for Excellence in Research in 1997.

CENTER ON TERRORISM AND IRREGULAR WARFARE

Established in 1998, the Center on Terrorism and Irregular Warfare focuses the research capabilities of its staff and of the Naval Postgraduate School (NPS) on an area of critical importance to the national security of the United States. Since September 11, staff from the Center have been assisting the Office of the Secretary of Defense, the Joint Staff and components of the Special Operations Command as they plan for and engage in the war on terrorism.

In providing this assistance, the Center's staff have drawn on a well-established body of relevant research. The Center's work concentrates on domestic and international terrorism, and other forms of irregular warfare, whether waged by sub-state groups against established governments or by states against each other. In studying this asymmetric conflict environment, the researchers emphasize the effect of the information and communication revolutions on this mode of conflict. As part of this effort, and in keeping with the strengths of the Naval Postgraduate School, the Center's work pays particular attention to emerging threats to the national infrastructure. Center staff also work to develop new, formal methods for evaluating and simulating the decision processes, actions, and life cycles of sub-state groups and their interactions with governments. Finally, the Center emphasizes analysis of Special Operations and Special Operations Forces, the military units whose primary responsibility is irregular warfare and countering terrorism. In all that it does, the Center strives to produce timely, innovative, interdisciplinary analysis relevant to policy and operations.

Professor Arquilla lectures students working towards their M.S. degree in Defense Analysis.

One of the great strengths of the Center is its association with the Department of Defense Analysis... Through this association, the Center draws on the operational expertise of Special Operations Officers. This arrangement enhances the educational experience of the students, while giving the Center's research its singular blend of analytical rigor and operational understanding.

One of the Center's first efforts, an analysis of the threat posed by cyberterrorism, displayed all of these characteristics. Prior to the publication of

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CYBERTERROR: WAITING FOR THE SKY TO FALL

CPT John W. Wheeler, United States Army
LT Patrick M. Foster, United States Navy
Capt Tyler K. Moore, United States Air Force

The thesis explores the threat of cyberterrorism and the ways in which the U.S. government might respond. The first part of the thesis analyzes the various levels of skill required by an organization to engage in cyberterrorism and the milestones for achieving these levels. The case studies examine the terrorist organizations (Aleph, formerly Aum Shinrikyo, and al Qaeda) and the hacktivist groups (MoS and the Chinese Honkers Union) with the greatest capabilities for engaging in cyberterrorism, concluding that these organizations and groups pose a threat to the United States. The second part of the thesis begins by surveying the organizations responsible for America's national cyber defense strategy. It then evaluates the model of defense in depth as a way of defending against cyber attacks, suggesting some methods for improving the current model. The thesis also considers methods of deterring cyber attacks. It concludes with an assessment of the future of cyberterrorism.

CENTER ON TERRORISM AND IRREGULAR WARFARE, *continued from page 4*

Cyberterror: Prospects and Implications (October 1999), discussion of this issue had focused on America's vulnerabilities. The Center's researchers asked instead what it would cost terrorists to exploit these vulnerabilities. Using a variety of analytical tools, including some drawn from organizational theory and psychology, the researchers concluded that the costs were significant, and therefore that the threat of cyberterrorism, while real, was not as great as most analysts had assumed. Because of its analytical rigor, this report had a major impact on subsequent discussions of cyberterrorism. Portions of it were read into the Congressional Record. This work has been updated in the thesis work of **CPT John Wheeler, USA**, **LT Patrick Foster, USN**, and **Capt Tyler K. Moore, USAF**. The thesis emphasis is on the organizational and strategic requirements for dealing with the threat of cyberterrorism.

Both the original research on cyberterrorism and the follow-on study were conducted by students at the Naval Postgraduate School, under the supervision of Center staff. One of the great strengths of the Center is its association with the Department of Defense Analysis, a Professional Military Education curriculum at NPS sponsored by the U.S. Special Operations Command. Through this association, the Center draws on the operational expertise of Special Operations Officers. This arrangement enhances the

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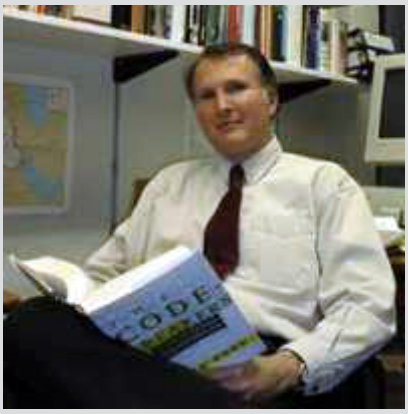
About the DIRECTORS

David Tucker is an Associate Professor in the Department of Defense Analysis and Co-Director of the Center on Terrorism and Irregular Warfare at the Naval Postgraduate School. Before coming to NPS, he served in the Office of the Assistant Secretary of Defense for Special Operations and Low-Intensity Conflict as the Deputy Director for Special Operations, and as a Foreign Service Officer in Africa and Europe. Before entering government service, he was the Director of the International Seminar in American Studies at the Claremont Institute and taught at the University of Chicago as a William Rainey Harper Fellow. He holds the Ph.D. from the Claremont Graduate School and is a member of the Board of Visitors of the Marine Corps University. His publications include "What's New about the New Terrorism and How Dangerous Is It?" *Terrorism and Political Violence* (Autumn 2001), "The RMA and the Interagency: Knowledge and Speed vs. Ignorance and Sloth?" (*Parameters*, Fall 2000); *Skirmishes at the Edge of Empire, the United States and International Terrorism* (Praeger, 1997), "Fighting Barbarians," *Parameters* (Summer 1998) and "Responding to Terrorism," *Washington Quarterly* (Winter 1998).

David Tucker

John Arquilla is an Associate Professor in the Department of Defense Analysis and Co-Director of the Center on Terrorism and Irregular Warfare at the Naval Postgraduate School. He earned his degrees in international relations from Rosary College (B.A., 1975) and Stanford University (M.A., 1989; Ph.D., 1991). His teaching includes courses in the history of special operations, international political theory, the revolution in military affairs, and information age-conflict. He has written *Lessons from the War with Saddam Hussein* (RAND, 1991) *Dubious Battles* (Crane Russak, 1992), and *From Troy to Entebbe* (University Press of America, 1996), as well as many articles, book chapters, and monographs on a wide range of topics in security affairs. He is best known for his collaborative RAND studies with David Ronfeldt, notably *Cyberwar is Coming!* (1993) and *The Advent of Netwar* (1996). Their book *In Athenas Camp* (1997) explores the many political, social, and military dimensions of the future of conflict. Their most recent books are *Swarming and The Future of Conflict* (2000), and *Networks and Netwars* (2001).



John Arquilla

THE CROSSBOW PROJECT

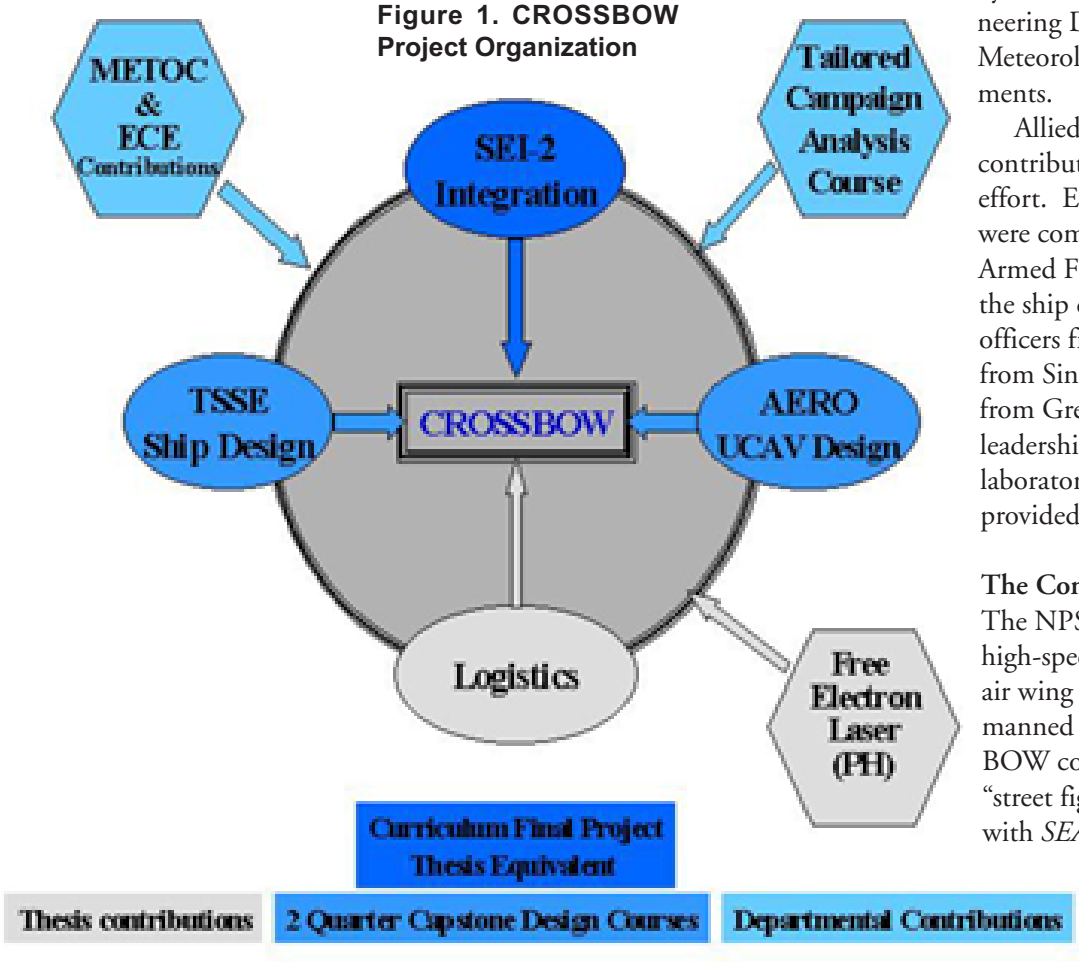
Naval Postgraduate School (NPS) students from across campus and from a variety of curricula recently completed a yearlong study and assessment of small, fast, surface combatants operating in large groups that are capable of distributed combat operations. The study effort required a level of interdisciplinary and interdepartmental collaboration not previously attempted at NPS. The final product is a concept called CROSSBOW, and is a strong demonstration of the School's ability to conduct large-scale investigations of relevant Navy issues.

The Project

The CROSSBOW project originated with the President of the Naval War College, who proposed studies to determine the technical feasibility and operational worth of CORSAIR -- a small, high-speed aircraft carrier concept. The central intent was to investigate the extent to which new technology and changing strategic environment warrant rethinking the relative merits of dispersion versus concentration and attendant economies of scale.

NPS elements contributing to the project are presented in Figure 1. The second cohort of students enrolled in the Systems Engineering and Integration (SEI) Curriculum were assigned CROSSBOW as their integration project. Students in the Total Ship Systems Engineering (TSSE) Capstone Ship Design Courses constituted the ship design team. The Capstone Aircraft Design Courses provided the air vehicle design team. Students from the Graduate School of Business and Public Policy produced a thesis on requirements and cost of CROSSBOW logistics and maintenance. A contributing thesis explored free electron lasers as "electric warship" weapons. In addition, the Operations Research Department tailored an existing campaign analysis course for the express purpose of evaluating a notional CROSSBOW force in scenarios representing the full spectrum of conflict. Also, the project benefited greatly from expertise and advice provided by the Electrical and Computer Engineering Department, as well as the Meteorology and Oceanography Departments.

Figure 1. CROSSBOW Project Organization



Allied officers made significant contributions to the CROSSBOW effort. Eight of the fifteen SEI students were combat officers from the Singapore Armed Forces. The eleven members of the ship design team included two naval officers from Turkey, one MOD civilian from Singapore and one naval officer from Greece. Finally, senior naval leadership, Navy and government laboratories, and industry visitors provided valuable insights.

The Concept

The NPS students chose to pursue a high-speed ship design that supports an air wing composed primarily of Unmanned Air Vehicles (UAVs). CROSSBOW combines a *SEA LANCE* (or "street fighter") variant (*SEA LANCE II*) with *SEA ARCHER* (a small, high-speed UAV Tactical Support Ship), and *SEA QUIVER* (a

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THE CROSSBOW PROJECT, *continued from page 6*

notional high-speed support ship). The *SEA ARCHER* air wing comprises eight multi-mission SEA ARROWs, Unmanned Combat Air Vehicles (UCAVs), eight multi-mission support UAVs, and two MH-60 multi-mission helicopters. This notional CROSSBOW force is shown in Figure 2.

Assessment

CROSSBOW was assessed for its capability to perform a wide variety of military missions, as summarized in Figure 3. The students assessed the CROSSBOW force as being highly capable as (a) a complement to Carrier Battle Groups (CVBGs) in performing operations in the littorals in high-intensity combat scenarios, and (b) a supplement to CVBGs providing sea-based forward presence in low- to medium-threat environments. The students concluded: "CROSSBOW provides the stunning jab

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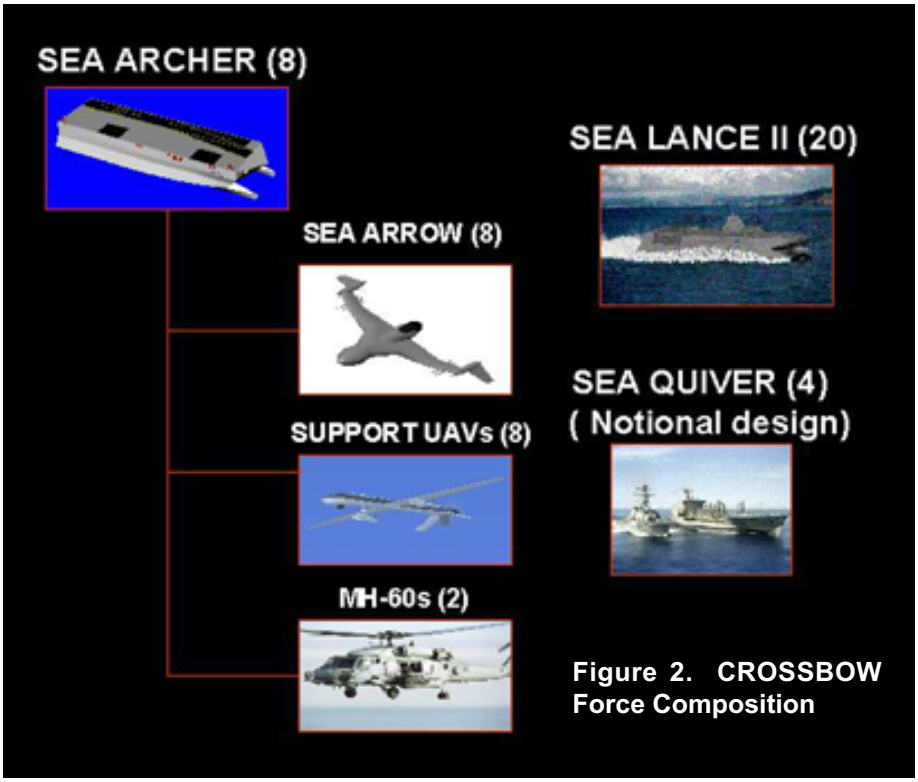

Figure 2. CROSSBOW Force Composition

THE CROSSBOW TEAM

SEA ARROW (Air Vehicle) Design Team

LCDR Christopher D. Junge, USN (M.S. in Aeronautical Engineering, December 2001)
LT Jeremy D. Brunn, USN (NPS/Test Pilot School Cooperative Program)
Capt Peter J. Brown, USMC (Aeronautical Engineering Curriculum)
LT Kurt W. Muller, USN (Combat Systems Science and Technology Curriculum)
LT Bryan J. Fetter, USN (NPS/Test Pilot School Cooperative Program)
LT Michael R. Mansisidor, USN (Aeronautical Engineering Curriculum)
LT Steven C. Roberto, USN (NPS/Test Pilot School Cooperative Program)
LT Armen H. Kurdian, USN (NPS/Test Pilot School Cooperative Program)

SEA ARCHER (Ship) Design Team

LT Joe Keller, USN (Naval/Mechanical Engineering Curriculum)
LCDR Rabon Cooke, USN (M.S. in Mechanical Engineering, December 2001)
LTJG Mersin Gokce, Turkish Navy (Naval/Mechanical Engineering Curriculum)
LTJG Orhan Barbaros Okan, Turkish Navy (Naval/Mechanical Engineering Curriculum)
LT Scot Searles, USN (M.S. in Applied Physics, December 2001)
Mr. Ivan Ng, Singapore Ministry of Defense (M.S. in Systems Engineering and Integration, December 2001)
CDR(sel) James Ivey, USN (M.S. in Mechanical Engineering, December 2001)
LT Antonios Dalakos, Hellenic Navy (M.S. in Mechanical Engineering, December 2001)
LT Peter LaShomb, USN (Electronic Systems Engineering Curriculum)
LT Ryan Kuchler, USN (Electronic Systems Engineering Curriculum)
LT Brad Stallings, USN (M.S. in Electrical Engineering, December 2001)

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THE CROSSBOW PROJECT, *continued from page 7*

while the CVBG delivers the knockout punch."

In addition, the project considered cost, advantages of distributed combat capability, and technical feasibility. Estimates of the costs to acquire, operate, and support a CROSSBOW force of 32 ships and 144 aircraft appear reasonable: about $11.3 B (constant FY02 dollars) for acquisition and $410M per year in Operations and Support (O&S). The project also discovered significant benefits from distributed combat forces. These included a more diffuse center of gravity, which complicates enemy attacks on the force. Because of their relatively small size, *SEA ARCHER* and *SEA LANCE II* are "combat consumables," in that loss of one vessel does not constitute a catastrophic loss of overall combat capability. In addition, distributed combat forces have greater ability to mount multi-axis attacks, and therefore pose more difficult problems for an adversary.

While the technology to field CROSSBOW is not fully in hand at present, there is good reason to believe that it could be by 2012. Developing the technology could, in turn, result in a deployable CROSSBOW force in 2020. Studies and assessments of availability (and potential availability) of key technologies were pervasive in all aspects of the project. Technological issues were an integral part of the ship and air vehicle design projects. In addition, SEI students undertook a number of individual supporting studies of various technical issues including command and control networks, automated ship operations, as well as means to defend against air, submarine and mine threats.

Bottom Line Conclusions

The project concluded that CROSSBOW is a highly promising concept. It has significant capabilities for a wide variety of naval missions particularly in the littorals. The CROSSBOW force itself is highly flexible and can be a useful complement to a Carrier Battle Group. The depth of study the CROSSBOW project could undertake does not support an immediate and unqualified endorsement. However, the

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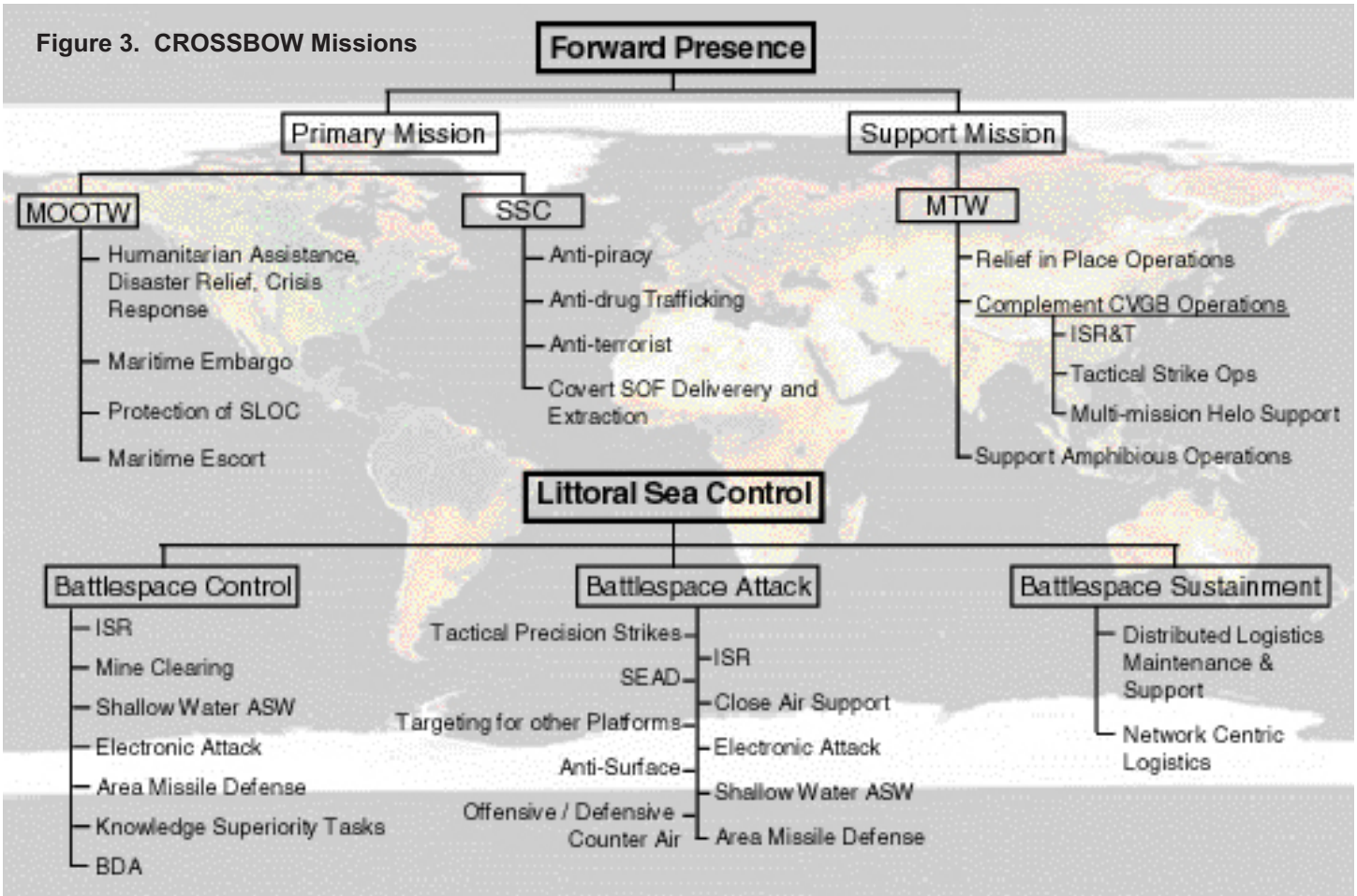
Figure 3. CROSSBOW Missions



THE CROSSBOW PROJECT, *continued from page 8*

concept deserves serious consideration. It also warrants further exploration through development of relevant technologies and operational experimentation.

Also, the CROSSBOW project is an excellent example of NPS in its role as the Navy's Corporate University. NPS students, with faculty guidance and assistance, have undertaken interdisciplinary, integrated, imaginative, broad-gauge research of a topic that is both highly sensitive and very important. We believe the project convincingly demonstrates NPS's ability to achieve educational excellence while simultaneously undertaking research that is relevant to the Navy's future.

THE CROSSBOW TEAM, *continued from page 7*

SEI-2 (Integration) Team
LT David Bauer, USN (M.S. in Systems Engineering and Integration, December 2001)
LT Brent Carroll, USN (M.S. in Systems Engineering and Integration, December 2001)
MAJ Paul Chew, Singapore Army (M.S. in Systems Engineering, December 2001)
LT Paul Darling, USN (M.S. in Systems Engineering, December 2001)
MAJ Khee Loon Foo, Singapore Army (M.S. in Systems Engineering and Integration, December 2001)
CAPT Jude Ho, Singapore Army (M.S. in Systems Engineering and Integration, December 2001)
LT Lance Lantier, USN (M.S. in Systems Engineering and Integration, December 2001)
MAJ Lawrence Lim, Singapore Army (M.S. in Systems Engineering, December 2001)
CDR Richard Muldoon, USN (M.S. in Systems Engineering, December 2001)
MAJ Cheow Siang Ng, Singapore Army (M.S. in Systems Engineering and Integration, December 2001)
LT Glen Quast, USN (M.S. in Systems Engineering and Integration, December 2001)
LT Bruce Schuette, USN (M.S. in Systems Engineering and Integration, December 2001)
MAJ Daniel Siew, Singapore Air Force (M.S. in Systems Engineering and Integration, December 2001)
MAJ Chun Hock Sng, Singapore Air Force (M.S. in Systems Engineering and Integration, December 2001)
MAJ Victor Yeo, Singapore Army (M.S. in Systems Engineering and Integration, December 2001)

Logistics Team
LCDR Joe F. Ray, USN (M.S. in Management, December 2001)
LCDR William W. Edge, USN (M.S. in Management, December 2001)
LCDR Gerald P. Raia, USN (Systems Inventory Management Curriculum)
LT Kenneth J. Brown, USN (M.S. in Management, December 2001)

Free Electron Laser Contributor
Mr. Ivan Ng , Singapore Ministry of Defense (M.S. in Applied Physics, December 2001)

Faculty Advisors included:
Distinguished Professor David W. Netzer, Dean of Research
Dr. Phillip DePoy, Director, Institute for Defense Systems Engineering and Analysis
Professor Conrad Newberry, Department of Aeronautics and Astronautics
Professor Charles Calvano, Department of Mechanical Engineering
Senior Lecturer Robert Harney, Institute for Defense Systems Engineering and Analysis
Senior Lecturer David Olwell, Department of Operations Research
CDR Mark Rhoades, USN, Graduate School of Engineering and Applied Sciences
Senior Lecturer Wayne Hughes, Graduate School of Operational and Information Sciences
Lecturer Brad Naegle, Graduate School of Business and Public Policy
Senior Lecturer Donald Eaton, Graduate School of Business and Public Policy
Associate Professor Keebom Kang, Graduate School of Business and Public Policy
Senior Lecturer Raymond Franck, Graduate School of Business and Public Policy
Professors Emeriti Patrick Parker and Michael Sovereign and other advisors for specialized supporting studies accomplished by SEI-2 students.

J-9 EXPERIMENTATION TEAM SPONSORS NPS REPRESENTATION AT THE FOURTH ANNUAL INTERNATIONAL CONFERENCE ON ELECTRONIC COMMERCE RESEARCH

Associate Professor Alex Bordetsky of the Department of Information Sciences, Graduate School of Operational and Information Sciences at the Naval Postgraduate School, chaired the Decision Support Technologies in Government E-Business session of the Fourth International Conference on Electronic Commerce Research (ICECR-4) in Dallas, 8-11 November 2001.

ICECR-4 brought together government, academic and industrial researchers in the field of Electronic Commerce (EC) to discuss new technological developments and their implications for EC, as well as technological issues that need to be addressed to further the effectiveness and efficiency of EC. The conference combined research tracks where technical papers were presented with industrial tracks consisting of panels, plenary speakers and exhibits.

EC has emerged as a dramatic new mode of business. Today, almost every company and government agency is either using or considering the use of EC. Advances in telecommunications and automated processes are already forcing dramatic changes in a variety of industries, ranging from banking and finance to music and entertainment. Yet, the EC space is still in a relatively early state of evolution, and many of the significant advances in understanding and implementing EC are occurring concurrently in government, academia and industry.

The traditional sequential process of technology innovation followed by technology transfer no longer applies. Thus, dialogue on this field between government, academia and industry is important. As EC spans a wide range of reference disciplines, forums focusing on EC research are necessary to stimulate the necessary interactions and knowledge sharing across this broad community.

General chair of the conference and Editor-in-Chief of the *Electronic Commerce Research Journal*, Professor Bezalel Gavish of the Edwin L. Cox School of Business, Southern Methodist University, stated, "The annual conference and subsequent *Electronic Commerce Research Journal* serves as an excellent forum for stimulating and disseminating research into all facets of electronic commerce - from research into core enabling technologies to work on assessing and understanding the implications of these technologies on societies, economies, businesses and individuals."

ICECR-4 concentrated on theoretical as well as empirical research that leads to better understanding of electronic commerce and its implications. The conference initially targets academics and professionals involved in electronic commerce research and the application and use of the Internet, but managers, consultants, decision-makers and developers who value the use of electronic commerce research results benefit from the forum as well.

Other ICECR-4 sessions included Global E-Commerce Research, Procurement, Internet Business and Strategy, EC Technologies, Web Technologies, Security Aspects in EC, Economic Models, Trust Models in E-Commerce, and Negotiations. Plenary speakers included Mike Conner, Chief Technical Officer for Web Services and Distinguished Engineer, IBM, USA ("Web Services: The Next Horizon of e-Business") and Boaz Golany, Department of Industrial Engineering and Management, Haifa, Israel ("Dealigence - Negotiated Transaction Systems and Advanced Commerce Technologies."

ICECR-4 brought together government, academic and industrial researchers in the field of Electronic Commerce (EC) to discuss new technological developments and their implications for EC, as well as technological issues that need to be addressed to further the effectiveness and efficiency of EC. The conference combined research tracks where technical papers were presented with industrial tracks consisting of panels, plenary speakers and exhibits.

NPS presenters at ICECR-4 included **Lecturer George A. Zolla, Jr.**, Department of Information Sciences ("Web-Based Information Management of Maintenance Errors in Aviation Mishaps"), **Assistant Professor Mark Nissen,** Graduate School of Business and Public Policy ("An Empirical Investigation of e-Employment Market Designs"), and graduate students **Capt Chris Collins, USMC,** ("Geographically Distributed Joint Decision Support Systems for Joint Logistics Operations") and **LCDR Tim Thate, USN** ("Identifying Collaborative Tools for Combined Joint Task Force "Focused Logistics" to Support "Rapid Decisive Operations"). The presentations were well received

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J-9 EXPERIMENTATION TEAM SPONSORS NPS REPRESENTATION, *continued from page 10*

by the international forum and directly contributed to the conference dynamics. These papers are published in the conference proceedings and will be considered for publication in the *Electronic Commerce Research Journal*.

The presentations by the NPS students at the conference reflect the results of Professor Bordetsky's class work for the J-9 Experimentation Team. This team, led by **Associate Professor Bill Kemple**, Department of Information Sciences, conducts research in support of major Department of Defense programs and operational commands. The purpose of this work is to contribute directly to the near- and long-term success of those organizations. Dr. Kemple is also the NPS Principal Investigator for the Office of Naval Research sponsored Adaptive Architectures for Command and Control Research Project.

LCDR Tim Thate, USN, (left) and Associate Professor Alex Bordetsky (right), took part in ICECR-4.

The J-9 Experimentation Team provides the opportunity to perform thesis research in a wide range of military application areas and provides funding for faculty and student travel for work and study directly supporting or related to J-9 initiatives and projects. J-9 focuses its primary efforts in Operations Analysis, Network Centric Operations, Experimentation, and Modeling and Simulation. Current J-9 Experimentation Team studies target Rapid Decisive Operations (RDO) concepts and tasks to include Joint Interactive Planning (JIP), Adaptive Joint Command and Control (AJC2), and Common Relevant Operational Picture (CROP).

Dr. Bordetsky leads JIP Studies which strive to provide for integrated, parallel planning and execution actions supporting the Joint Force Commander (JFC) and staff, subordinate and supporting commands, and across all allied and coalition forces, increasing unity of effort and speed of command. RDO is an "integrating" concept oriented at a high end, small-scale contingency in the 2015 timeframe. It provides context and focus for the "functional" concepts including: Strategic Deployment, Focused Logistics: Enabling Early Decisive Operations, Adaptive Joint Command and Control, Joint Interactive Planning, Attack Operations Against Critical Mobile Targets, Information Operations, Common Relevant Operational Picture, plus emerging ideas such as Effects-based Operations and Assured Access. RDO describes how a joint force commander can determine and employ the right balance of land, sea, aerospace, and information-based capabilities in an intense, focused, non-linear campaign to rapidly defeat an adversary's strategic and operational centers of gravity. Although RDO focuses on a high-end small-scale contingency, its principles can be applied to military engagements from operations other than war through major theater of war.

The Internet and the World Wide Web have brought a fundamental change in the way that individuals access data, information and services. Individuals have access to vast amounts of data, to experts and services that are not limited in time or space. This has forced business and government to change the way in which it conducts transactions with end customers and with other businesses, resulting in the development of a global market through the Internet. Go to the ICECR-4 and J-9 Sites: http://tecom.cox.smu.edu/icecr4/index.html.

DEVELOPMENT OF A SIX-DEGREE-OF-FREEDOM MODEL FOR A FULLY DEPLOYED G-12 AGAS DELIVERY SYSTEM

LCDR Christopher D. Junge, United States Navy
Master of Aeronautical Engineering – December 2001
Advisors: Associate Professor Richard M. Howard, Department of Aeronautics and Astronautics, Dr. Vladimir Dobrokhodov, National Research Council Research Associate, and Associate Professor Wei Kang, Department of Mathematics

In 1997, the United States Air Force Advisory Board published a report entitled, "New World Vistas, Air and Space Power for the 21st Century." The study identified a critical need to improve Point-of-Use Delivery, in which operational forces can rely on precision airdrop to increase their levels of autonomy and self-sufficiency. Guiding an airdrop delivery system to intended target points of touchdown using low-cost flat circular parachutes has become an important goal. The G-12 Airdrop Delivery System is a delivery system consisting of an A-22 container, capable of carrying a payload of up to 2200 pounds, connected rigidly to the G-12 flat circular parachute by suspension lines. The G-12 parachute is a nylon parachute with 64 suspension lines with an uninflated canopy diameter of 64 feet. Together with an onboard sensor suite and guidance, navigation and control software driving pneumatic muscle actuators to steer the descending parachute and payload, this system comprises the U.S. Army Affordable Guided Airdrop System (AGAS), currently undergoing research, development and testing. The thrust of this effort has been to develop a high-fidelity six-degree-of-freedom (6-DOF) dynamic model of the parachute system, involving such issues as a valid aerodynamic model over a range of angles of attack and the inclusion of an apparent-mass tensor in an attempt to capture the coning motion during descent and to accurately predict the parachute's trajectory in a measured wind profile. Previous models based on three degrees of freedom have proven acceptable in predicting the G-12 delivery systems trajectory, but did not capture the coning motion associated with parachute systems. This thesis focused on the development of a 6-DOF model for a rigid-body system to ascertain if a higher-fidelity model could provide increased delivery accuracy. The model, developed in Mathworks software SIMULINK™, used state-space relationships for the equations of motion and incorporated the effects of the air mass that surrounds the parachute system throughout its descent. Compared to the limited drop data available, the 6-DOF model produced trajectory results similar to those achieved with the lower-fidelity 3-DOF model, while additionally capturing the basic dynamic behavior and coning motion. Coning frequencies in pitch and roll from the simulated drops matched those of drop-test data to within 5%. Continued modeling of aerodynamic coefficients and the apparent mass tensor using parameter estimation techniques, however, is recommended to improve the models ability to accurately predict the dynamic motion and trajectory of the G-12.

UNCONVENTIONAL ASSISTED RECOVERY (UAR): HISTORICAL CASE STUDY ANALYSIS AND QUANTITATIVE FEASIBILITY ASSESSMENT

Capt Eric A. Patterson, United States Marine Corps
Master of Science in Defense Analysis – December 2001
Advisor: Associate Professor Gordon McCormick, Department of Defense Analysis

During the Gulf War, 34 Coalition pilots were shot down, yet only six were recovered by conventional CSAR. Consequently, SOF planners began to consider the impact of integrated air defenses upon personnel recovery and to consider a more proactive method of recovery. While serving as a member of the SOCCENT Unconventional Warfare Working Group and as the lead planner for the first UAR training program and exercise for 3rd Special Forces Group, it was observed that there was little consideration of similar historical operations and that operators were skeptical of UAR. This thesis demonstrates, via historical case studies, that UAR is by no means a new mission profile. The purpose of this thesis is to assist the special operations community with the development of doctrine for UAR and to offer SOF commanders a feasibility assessment tool. This purpose was achieved by: (1) Developing a historical perspective of similar missions through case study analysis to determine, via controlled comparison, the key independent variables that determine the success of ground-based SOF recovery operations, and by (2) Conducting quantitative modeling of UAR to determine, through a range of numerically based conditions, a range of feasibility and doctrinal implications for UAR.

STUDENT RESEARCH

AN IDENTIFICATION AND POSSIBLE METHOD OF COLLECTION/REPORTING OF UNDER-REPORTED SMALL BUSINESS UTILIZATION DATA FOR THE SPACE AND NAVAL WARFARE SYSTEMS COMMAND

Mark R. Schweer, DoD Civilian
Master of Science in Contract Management – December 2001
Advisors: Associate Professor Ira Lewis, Graduate School of Business and Public Policy, and Mr. Tim Dowd, Space and Naval Warfare Systems Command

Many acquisition organizations have difficulty meeting their mandated small business utilization goals. Much literature is rightly dedicated to methods of increasing this utilization. However, small businesses are actually making a greater contribution to an organization's mission than the current reporting system demonstrates. Mis-reported, under-reported and unreported small business utilization comprises a significant percentage of an acquisition organizations total procurement obligations for which the current reporting system grants no credit. The areas of first-tier subcontracting, second-tier subcontracting, Interagency acquisition, GSA FSS orders, indirect costs, Other Transactions, Micro-purchases and contracts under $500K were analyzed to quantify the amount of reporting variance at the Space and Naval Warfare Systems Command. First and second-tier subcontracting were found to account for the majority of mis/unreported utilization, and are the only areas whose inclusion in SPAWAR's utilization statistics is clearly advantageous. Research demonstrates that an additional 9-16% of SPAWAR's procurement dollars end up in the hands of small businesses by granting SPAWAR credit for this small business utilization. To effect a change in the reporting system, improvements must be made in an automated system to collect and report subcontracting utilization data, the use of a new reporting metric, and the issuance of clear policy guidance.

STUDENT FELLOWSHIPS AWARDED BY THE SPACE AND NAVAL WARFARE SYSTEMS CENTER-SAN DIEGO

The Space and Naval Warfare Systems Center-San Diego (SSC-SD) sponsors a Research Fellowship Program at the Naval Postgraduate School (NPS). The program was instituted to promote NPS partnership with SSC-SD, address SSC-SD's research focus areas, lay the groundwork for future technical and project management assignments, and foster long-term professional associations with SSC-SD's technical personnel and management. There are two rounds of awards each year, one in early spring, the other in the fall. NPS students submit proposals that are reviewed by the technical staff of SSC-SD and approved by the SSC-SD Commander, CAPT P.A. Miller,

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ACQUISITION STRATEGIES FOR AGING AIRCRAFT: MODERNIZING THE MARINE CORPS' CH-53E SUPER STALLION HELICOPTER

Capt Matthew J. Fowler, United States Marine Corps
Master of Science in Management – December 2001
Advisors: Lecturer David F. Matthews, Senior Lecturer Donald R. Eaton, and Associate Professor William Gates, Graduate School of Business and Public Policy

This thesis explores various acquisition and contracting issues relevant to the proposed United States Marine Corps CH-53E Super Stallion helicopter modernization. The research includes a preliminary cost and operational effectiveness analysis that identifies critical requirements issues and potential acquisition and contracting pitfalls. Cost and effectiveness modeling draws on multi-attribute decision analysis and simulation software to capture the complexities and uncertainties inherent in this modernization program. Based upon this analysis, literature research and interviews with acquisition managers and industry professionals, pertinent issues for developing an acquisition strategy are analyzed and discussed.

Some acquisition strategy issues analyzed include risk management, cultural and institutional obstacles to success, competition, integrated contract management, opportunities for tailoring and streamlining, opportunities for exploiting the most recent revision of the Department of Defense 5000 Series, contractor logistic support, operating and support cost reduction and control and finally, political considerations. Various incentive arrangement structures are suggested to ensure programmatic success. Lessons and methodologies that can be extrapolated from this case study to other aging aircraft modernization programs are identified to aid in developing other acquisition strategies.

ROCKET PLUME TOMOGRAPHY OF COMBUSTION SPECIES

Capt Joshua M. Kutrieb, United States Air Force
Master of Science in Astronautical Engineering – December 2001
Aeronautical and Astronautical Engineer – December 2001
Advisors: Research Assistant Professors Christopher Brophy and Jose Sinibaldi, Department of Aeronautics and Astronautics, and Associate Professor Ashok Gopinath, Department of Mechanical Engineering

Interest in accurate detection and targeting of aggressor missiles has received considerable interest with the national priority of developing a missile defense system. Understanding the thermal signatures of the exhaust plumes of such missiles is key to accomplishing that mission. Before signature models can be precisely developed for specific rockets, the radiation of the molecular or combustion

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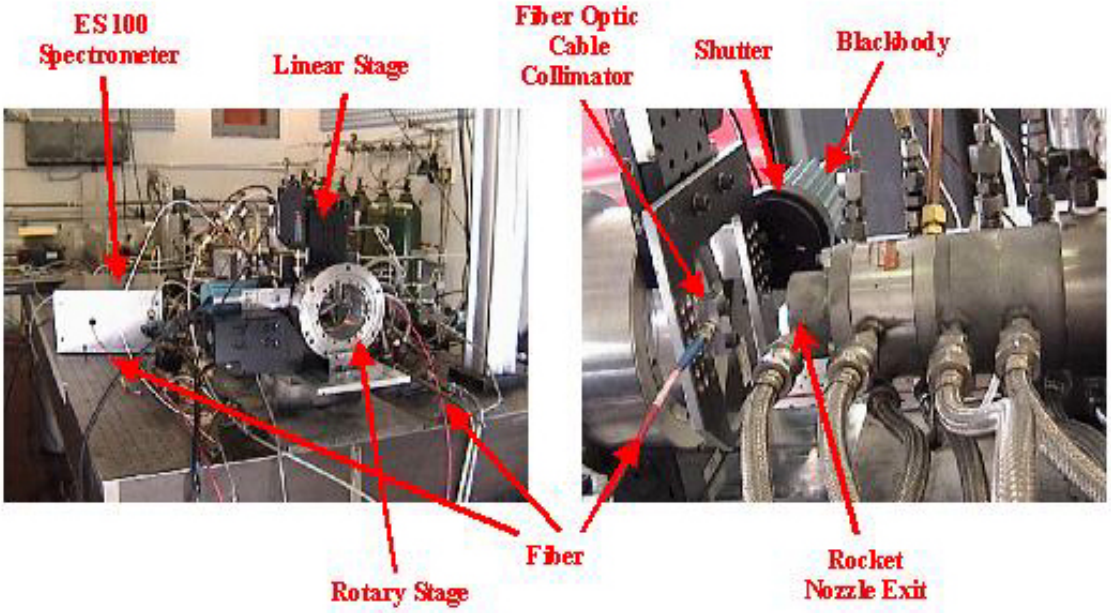

Aft view of scanning hardware (left). Side view of rocket engine and scanning hardware (right).

STUDENT FELLOWSHIPS, *continued from page 14*

USN. The latest awards were just announced. These students join the previous 45 receiving fellowship awards. The fellowship includes a $10,000 award to support the students thesis research.

Capt Andrew G. Chapman, USMC, pursuing the M.S. in Electrical Engineering, is working with faculty advisor, **Assistant Professor Todd Weatherford**, Department of Electrical and Computer Engineering, on "Single-Event Transient Measurements in Silicon-on-Insulator MOSFETs."

Capt Allen A. Harper, USMC, is working with faculty advisor, **LCDR Chris Eagle, USN**, on "Developing Training Material and Procedures for Securing Computer Networks through the Use of Vulnerability Assessment Techniques." Capt Harper is working towards an M.S. in Computer Science.

"Computer Controlled Optical Detector Characterization System to Support the Design and Evaluation of Multi-Color (IR/Laser) Quantum Well Photodetector (QWIP) Sensor Material," is the research topic of **LCDR Brian E. Herdlick, USN**. LCDR Herdlick is working towards the M.S. in Applied Physics. **Associate Professor Gamani Karunasiri** of the Department of Physics is his faculty advisor.

LT George Lawler, USN, is working with **Professor Valdis Berzins** of the Department of Computer Science. Working towards the M.S. degree in Computer Science, LT Lawler's thesis research will focus on "Federation Session Management Protocol (FSMP)."

Pursuing a Ph.D. in Software Engineering, **LTC J.F. Puett, III, USA**, will be working with faculty advisor **Professor Luqi** of the Department of Computer Science. His research topic is "Embedded Quality Function Deployment within the Computer Aided Software Evolution Model."

LT H.M. Vegter, USN, and **Capt D.T. Wallace, USMC**, both pursuing the M.S. in Information Technology Management, will be working with faculty advisor **Professor Dan Boger** of the Department of Information Sciences. Their joint project is titled, "Exploitation of Existing Voice Over Internet Protocol Technology to Provide Secure Voice Over Internet Protocol."

CENTER ON TERRORISM AND IRREGULAR WARFARE, *continued from page 5*

educational experience of the students, while giving the Center's research its singular blend of analytical rigor and operational understanding.

This blend of analysis and operational experience manifests itself clearly in the short-term work that the Center does in support of the operational forces. This work seeks to create operational efficiencies and open up new operational possibilities through the application of analytical techniques and some unconventional thinking. In addition, the Center's short-term work has supported the Intelligence Community by identifying possible threats and providing preliminary assessments of them.

The Center's interdisciplinary character derives from the professional education and experience of its staff, who bring to the Center's research the varied perspectives and analytical skills of political science, anthropology, economics, history, mathematics, organization science, and conflict modeling. The Center's research reflects this diverse array of expertise. Research products and activities have included:

- A mathematical model of clandestine organizations unsurpassed in its depiction of the dynamics of such organizations, including those that engage in terrorism. This model provides an essential tool for the current war on terrorism.
- A seminar war game in which, along with academics, individuals with experience in terrorist organizations participated. This war game developed a series of insights into the strategic and operational thinking of terrorists.
- An analysis of the social dynamics of hackers and terrorists, designed to understand what barriers, if any, exist to their collaboration. This research will be an important contribution to understanding the evolving character of cyberterrorism.
- A history of the Special Operations Command and its unique authorities and funding arrangements, designed to assess whether the Command might provide a model for organizing other DoD activities.

The Center's research also includes studies of ethnic cleansing; women in combat; human factors in special operations; the "new terrorism"; military innovation, using cases from the post-World War II history of Special Operations Forces; and decisionmaking in proliferation and counterproliferation. The Center has also developed and continues to update a cyberterror database.

To accomplish its goals, the Center has established joint research ventures with Carnegie Mellon University and the RAND Corporation. It works closely with scholars at these and other institutions. The Center is also affiliated with the Institute for Information Superiority and Innovation at the Naval Postgraduate School. In addition, the Center's staff have consulted with RAND, the Institute for Defense Analyses and Booz -Allen Hamilton.

Funding for the Center has come from components of the Special Operations Command, the Defense Intelligence Agency, the Office of the Assistant Secretary of Defense for Special Operations and Low-Intensity Conflict, the Office of Net Assessment (Office of the Secretary of Defense), and the Smith Richardson Foundation.

For further information on the Center and its work, please contact **Associate Professor David Tucker**, 831-656-3754, dctucker@nps.navy.mil.

ROCKET PLUME TOMOGRAPHY OF COMBUSTION SPECIES, *continued from page 14*

species within those plumes must be accurately predicted. A combination translation / rotation scanning diagnostic technique has been developed to map the combustion species of a rocket plume and characterize its radiation properties. Using a new infrared spectrometer and fiber optic cable technology to transmit the signal spectrum of interest, the custom designed mechanism can sweep through two dimensions of a steady-state rocket exhaust. A glow bar, or blackbody simulator, is shuttered on the opposite side of the plume, allowing the spectrometer to measure both the emission and absorption spectra. This thesis demonstrated the first time use of fiber optic cable to transmit infrared emission / absorption (E/A) spectra from a rocket plume to an infrared detector. This new fiber optic configuration allows for rapid translation and rotation around the rocket plume, establishing the capability for rapid spatial characterization of the combustion species present. Experimental results may then be compared to DoD rocket plume model predictions to highlight areas for improvement.

UNITED STATES NAVAL ACADEMY TRIDENT SCHOLAR PROGRAM

The United States Naval Academy instituted the Trident Scholar Program in 1963 to provide an opportunity for a limited number of exceptionally capable students to engage in independent study and research during their senior year. Under this program, midshipmen in the top 10 percent of their class at the end of the first semester of their junior year are invited to submit proposed research projects and programs of study for evaluation. Midshipmen selected to participate are afforded an unusually exciting educational experience, and there has been a gratifying response to the program. The number of scholars selected has ranged from a low of three to a high of sixteen. Nine scholars were in the Class of 2001 and fourteen scholars are in the Class of 2002.

Five of the projects are profiled here, with additional profiles forthcoming in future issues of the *NPS RESEARCH*.

AUTOPILOT AND SEARCH PATTERN CONTROL FOR MINIATURE MINE DETECTION VEHICLES

Benjamin A. Drew (Systems Engineering major)
Advisor: Associate Professor Carl L. Wick, Weapons and Systems Engineering Department

The Autonomous Underwater Vehicle is an unmanned vessel that is used in many applications including offshore oil industry, marine biology research, and salvaging in an effort to replace divers. As today's Naval Explosive Ordinance Disposal Units look for innovative, technological developments in minefield clearance and related missions clearing unexploded ordinance, the further employment of autonomous unmanned vehicles (AUV) is under strong consideration. Instead of developing systems of high complexity and cost, it is worthwhile to investigate the development of a clandestine AUV with a singular and simplistic mission. In this Trident Scholar Research Project, I propose to design and construct an engineering prototype miniature, efficient autonomous underwater vehicle, of dimensions consistent with the proposed mission, and to develop a control system that will allow it to search for a mine-like target. The vehicle and control will be designed to search in an energy efficient "gliding" configuration. Wings on the vehicle allow steerable gliding, which subsequently offers horizontal propulsion. As the AUV glides over an area, a fundamental sensor will control the search pattern (probably a magnetometer). At a particular depth, the AUV will use its energy source, a battery, or a buoyancy modification system to propel itself towards the surface and initiate the search pattern again. Using an accelerometer with two directions of inclination in order to measure pitch and yaw and through simple trigonometric equations, the system should be able to derive the orientation of the vehicle and recognizes any course changes that need to be made. A depth sensor will be added in order to maintain the search pattern in shallow waters. Finally, the use of a magnetometer (or compass) will be employed as a means of maintaining a search pattern turn rate and heading.

Midshipman Benjamin Drew

Fundamentally, for the purpose of this project, the AUV will consist of a small gliding body; a control system that executes a controlled search pattern and that initiates a propulsion system for the vehicle to recommence its search. The shape of the AUV is yet to be determined. With respect to the parameter uncertainties of the environment, emphasis will be placed on motion characteristics of vehicle body style, propulsion systems, and maneuverability. The external shape of the AUV is envisioned to be ray-like, similar to that of a triangle with a lifting surface, streamlined to avoid water

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AN ALL OPTICAL RECEIVER EMPLOYING DIFFERENTIAL PHASE SHIFT KEYING USING SELF-HOMODYNE DETECTION

Tarek S. Elmasry (Electrical Engineering major)
Advisors: Associate Professors R. Brian and Deborah M. Mechtel, Electrical Engineering Department

The goal of this project is to create a digital optical demodulator which can process information propagating at high data rates in an optical fiber. By being able to process data at a higher rate at the receiver more data can be sent over a transmission line. Most demodulators in commercial applications utilize electrical systems. Thus when an optical signal propagating in a fiber optic channel arrives at the receiver to be demodulated this conversion of the signal from an optical to an electrical format significantly slows down the processing speed. By optically processing the signal just before the electrical receiver, information can be transmitted at higher data rates. Many methods of building an optical demodulator have been tried using different digital signal processing techniques. In this project a demodulator will be designed for differential phase shift keyed (DPSK) data using self-homodyne detection without using a local oscillator. A local oscillator is often incorporated into the demodulator to provide a reference for the incoming data to be compared to so that this data can be interpreted. By ridding the receiver of the local oscillator the design of this receiver may be simpler than previously constructed receivers. In place of a local oscillator a 3-dB coupler and a delay line will be used. With this configuration the incoming signal will use itself as the reference.

Midshipman Tarek Elmasry and advisor Associate Professor R. Brian Jenkins

Before a hardware design is implemented, a computer model of all components of the receiver will be generated to determine the expected performance of all receiver components. The software package that will be used for this project is very comprehensive but additional modeling may be needed for effects that the package may ignore. In the research, channel effects such as dispersion and attenuation will be examined. In the receiver, most of the attention will be given to the effects of improper constructive and destructive interference occurring where the signal is compared to the reference. Other effects that will be examined include polarization mismatching and noise processes in receiver components.

The primary measure of receiver performance is the bit error rate for transmitted data. Research will be conducted primarily by sorting through scholarly journals on this topic. Much of this research will consist of analyzing the propagation path for the information carrying electromagnetic wave upon which modulation will take place. When the model is complete the receiver will be built and tested. Thus far research on this topic has been entirely theoretical. Actually building the receiver and getting it to work would be a major

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AUTOPILOT AND SEARCH PATTERN CONTROL, *continued from page 16*

resistance and simultaneously obtain the largest horizontal distance with the smallest vertical drop. The vehicle will contain an accelerometer to measure orientation with regard to gravity. In terms of maneuverability, predictive design equations involving dynamic motion parameters such as the effects of pitch, yaw, and vertical movement will be considered in order to maintain a level and defined approach across a search area. This Trident Project is an extension of ongoing AUV developmental prototypes under the direction of Associate Professor Carl Wick and Assistant Professor Daniel J. Stilwell, of the Weapons and Systems Engineering Department and in conjunction with the Naval Architecture and Ocean Engineering Department of the Naval Academy.

REACTION DIFFUSION EQUATIONS AND MORPHOGENESIS USING GALERKIN METHODS

Benjamin M. Heineike (Mathematics major)
Advisors: Professor Reza Malek-Madani and Associate Professor Sonia M. Garcia, Mathematics Department

Morphogenesis

The theory is that when stem cells are deciding when to differentiate, they receive chemical signals from "Morphogens." When these morphogens occur in the right patterns, they give the signals that cause the cells to generate biological patterns. For instance the dappling pattern on certain leaves or on the skin of leopards can be reproduced with these equations. Perhaps the mechanism behind many biological patterns is less complicated than previously speculated.

Midshipman Benjamin Heineike and advisor Professor Reza Malek-Madani

The Model: Reaction Diffusion Equations

These Partial Differential Equations are what we are using to model the interactions of our morphogens. These equations only take two processes into account: (1) The chemical reactions of the chemicals with each other, and (2) the diffusion of the chemicals across the tissue. (We leave out electromagnetic forces, internal cell structure, etc.). We would like to show that complex patterns could be produced assuming just these two processes. This model neglects some of the conditions known to be present in cells, for instance cell walls and electromagnetic forces, but we would like to show that these effects are negligible. This is a notion in mathematics referred to as complexity. Simple interactions on a local level giving rise to very complex patterns and self-organization at a global level.

Our particular equation is going to be a partial differential equation on R2 on a square region, and using a variety of convenient boundary conditions:

$\mathbf{u} = \begin{bmatrix} x \\ y \end{bmatrix}$ These are the concentrations of two chemicals

$\mathbf{u}_t = D\Delta\mathbf{u} + f(\mathbf{u})$

$\mathbf{u}_t$ is the change in concentrations with respect to time

D is a matrix of diffusion coefficients

$\Delta\mathbf{u}$ the laplacian of $\mathbf{u}$ which is like the second derivative with respect to space. We will assume that this is what diffusion depends on.

$f(\mathbf{u})$ is the reaction function. We will start out with the function $f(\mathbf{u})=\mathbf{u}(1-\mathbf{u})$. This is not realistic per se; it is just a common example. It is however possible.

As we progress, we will improve the model with realistic coefficients, realistic functions f, realistic boundary conditions and if we have time, perhaps another dimension.

The method that we will use to simulate these equations is a computational method known as the Galerkin (or Spectral) Method. The method states that we can approximate Partial Differential Equations of certain types with an infinite set of Ordinary Differential Equations. We then will decide at what level we must truncate this infinite set to get an accurate

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OPTICAL RECEIVER, *continued from page 17*

step forward in this field of research.

If the receiver does not behave as predicted then the model will be modified to describe what is occurring. Determining whether or not the receiver is performing in accordance with the model will be a major challenge for this project, especially when experiments are done at high data rates. Successful performance of this demodulator could pave the way to more significant progress in the design of optical systems. The primary application of this receiver would be military and commercial sectors.

BETTER OPTICAL LIMITERS

Peter D. Huffman (Chemistry major)
Advisors: Professor Jeffrey P. Fitzgerald, Chemistry Department, and Dr. James S. Shirk, Naval Research Laboratory

Optical limiters are devices that transmit light at low intensities, but block high intensity light, effectively keeping the amount of transmitted light below a certain level. Optical limiters have a wide variety of applications, and are of special interest to the Navy for protecting optical sensors and human eyes from directed laser weapons.

The most successful optical limiters known are various forms of metallated phthalocyanines, in particular lead and indium phthalocyanines. Yet further improvements are needed. The first part of this project involves the synthesis and examination of phthalocyanines metallated with thallium, whose proximity to lead and indium on the periodic table suggests that it will exhibit favorable optical limiting properties. As phthalocyanines are highly insoluble in many useful solvents, the synthesis will also include adding substituents to the phthalocyanine macrocycle in order to increase the solubility of the molecule for testing and application. The fact that unsubstituted thallium phthalocyanines have been made and reported in the literature suggests that the synthesis of substituted derivatives should be feasible.

Midshipman Peter Huffman with advisor Professor Jeffrey P. Fitzgerald

The second approach to improving optical limiters is to control the aggregation of molecules in solution. Lead phthalocyanines show a maximum in their optical limiting properties as the concentration increases, but these properties

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REACTION DIFFUSION EQUATIONS, *continued from page 18*

enough description of the behavior of the solution while keeping our computing time within reasonable limits.

PDE → Galerkin Method → n ODEs

We will do this by identifying a set of basis functions that depend only on space ϕ_i, and assume that the solution takes the form:

$$\mathbf{u(x,t)} = \sum_{i=1}^{\infty} a(t)\phi_i(x)$$

We will then take the original PDE, multiply it by the ϕ_is one at a time, and integrate over space. The number of times we do this is how many ODEs we are left with (they depend just on time after integrating out space. Also multiplying by ϕ_i makes them independent). Now we use a reliable ODE solver to simulate the solution.

The primary ODE solver that we will use will be Matlabs ODE 45, but we will compare our results with those obtained in Mathematica and with various Commercial-Off-the-Shelf (COTS) programs that solve PDEs (i.e. Femlab). We will write our code in Matlab, Maple, and Mathematica.

Some of the analysis that we will carry out will be:

- Comparing our method to other methods to see how they compare in
  - Computing time
  - Accuracy
  - Reproducibility
- Deciding how many ODEs you need to make the solution accurate enough
- Identifying conditions that lead to patterns
- Determining whether or not these conditions would be feasible in real reactions
- Creating interesting patterns with mathematics

ACTIVE CONTROL OF FAN NOISE IN DUCTS USING MAGNETIC BEARINGS

Jonathan P. Nelson (Systems Engineering major)
Advisors: Associate Professors George E. Piper and John M. Watkins, Weapons and Systems Engineering Department

The primary objective of this project is to demonstrate global noise attenuation of the fundamental frequency of a fan in an air duct. This will be achieved through the use of magnetic bearings. The projects secondary objective is to attenuate broadband frequencies created by the fan at all points in space.

As a fan turns within a duct or pipe (i.e. industrial heating, ventilation, or air conditioning units) sound is created simply by virtue of the fact that pressure waves are created at the fundamental frequency of the fan. However, the fan also creates harmonics of the fundamental frequency. In addition, turbulent airflow through the fan will cause additional noise. Therefore, broadband frequencies of noise exist, all due to a fan blowing air.

Midshipmen Jonathan Nelson and advisor Associate Professor George Piper

Usually, rotating shafts are supported by conventional ball bearings. However, this project will use active magnetic bearings consisting of two radial bearings and one thrust bearing. The radial bearings will support the fan shaft radially while the thrust bearing will control axial movement. While the bearings main function is to support the fan shaft, it will also perform the critical function of active sound control.

Active sound control is the method of determining the frequency and amplitude of sound created and then using another source to output a sound wave of equal amplitude and frequency, but 180 degrees out of phase to achieve destructive interference.

Microphones will be positioned at key places throughout the duct in order to observe the full extent of sound produced within the duct. Some of these microphones are connected to a Digital Signal Processor (DSP), a microprocessor, which contains the active sound control program needed to vibrate the fan shaft in a pattern opposite to the original sound patterns.

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BETTER OPTICAL LIMITERS, *continued from page 19*

diminish at higher concentration. Scientists believe that the most successful optical limiter is a solution of lead phthalocyanines at such a concentration that the molecules aggregate primarily as dimers. The second part of this project involves the synthesis of covalently linked phthalocyanine macrocycles, which would essentially force the molecules to dimerize in solution. These "clamshell" structures have been reported in the literature, but not for optical limiting applications.

The two prongs of the project may be merged if thallium phthalocyanines are found to be effective optical limiters, and the "clamshell" structures may be metallated with thallium. Based upon the optical limiting properties found for the "clamshell" structures, a tetramer phthalocyanine molecule may be synthesized (covalently linking four phthalocyanine monomers) which may act as a pair of phthalocyanine dimers.

So far, both t-butyl and cumylphenoxy substituted clamshell phthalocyanines have been synthesized. A metallation of the cumylphenoxy phthalocyanine dimer with lead appears successful based upon NMR and UV-VIS spectroscopy analysis. The maximum absorbance for the lead metallated phthalocyanine dimer (and a cumyl-phenoxy substituted lead phthalocyanine monomer) occurs at a longer wavelength than for similar phthalocyanine dimers metallated with other metals (around 720 nm). Preparations are being made to metallate simple phthalocyanine monomers with thallium and then proceed to a dimer metallation.

THE NAVAL POSTGRADUATE SCHOOL AND THE NATIONAL UNIVERSITY OF SINGAPORE ESTABLISH A NEW JOINT DEFENSE TECHNOLOGY AND SYSTEMS CURRICULUM

The Naval Postgraduate School (NPS) and the National University of Singapore (NUS) have collaborated to establish and operate a Singapore based institute named Temasek Defence Systems Institute (TDSI) for graduate education and research in the area of defense technology and systems engineering and analysis. The TDSI is part of the National University of Singapore. The premier project of TDSI is the new joint NPS/NUS Defense Technology and Systems Curriculum that will begin at NUS in July 2002. The initial class will be comprised of about 30 Singapore officers, seven other International officers and three U.S. officers.

This joint Naval Postgraduate School and National University of Singapore curriculum is designed to provide qualified personnel with an advanced understanding of the dynamic complexity of military warfare for exploiting emerging technologies to achieve war-fighting advantages. The joint curriculum provides a platform for the education and the integration of operational staff and defense technologists to plan, design, develop, create, operate and sustain Integrated Military Forces of the 21st Century.

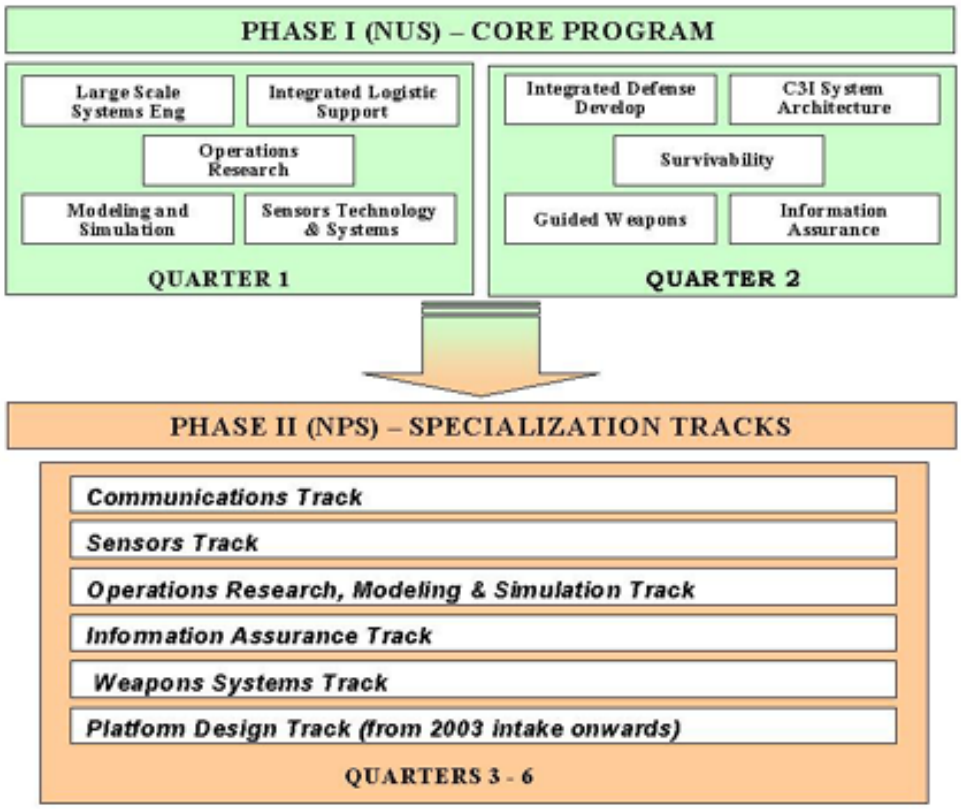

Figure 1. NPS/NUS Defense Technology and Systems Curriculum

The first two quarters of the 18-month joint curriculum will be conducted at NUS by faculty from NUS and NPS and will provide a firm grounding in key technical and project management skills (see Figure 1). The third to sixth quarters will be conducted at NPS, where the students will enter into designated specialization tracks such as Communication Systems, Sensor Systems, Operations Research, Information Assurance, and Guided Weapons Systems. The students will blend their operational experience with a thorough technical education to expeditiously integrate new technological capabilities into operational applications. Upon successful completion of the coursework, a comprehensive integrated project, and thesis research, the student will be awarded a joint NPS/NUS Master of Science degree in the appropriate technical field, such as Electrical Engineering, Computer Science, Mechanical Engineering, Operations Research, etc.

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ACTIVE CONTROL OF FAN NOISE,

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Other microphones will be used to monitor the sound created before and after the active sound control system is turned on.

Although active sound control systems traditionally use a secondary speaker to cancel sound from the primary noise source, this experiment will use the fan equipped with magnetic bearings as the secondary speaker. As sound is emitted from the fan, the active sound control system will attempt to dampen the fan noise. Because the primary and secondary sound sources are collocated, control of sound throughout the duct is theoretically possible. This project will attempt to demonstrate this global control of noise experimentally.

NPS AND LOCKHEED-MARTIN MISSILES AND SPACE OPERATIONS SIGN STATEMENT OF INTENT TO ESTABLISH CHAIR PROFESSORSHIP

A Statement of Intent between the Naval Postgraduate School and Lockheed Martin Missile and Space Operations has been signed to establish the Lockheed Martin Missiles and Space Operations (LM-MSO) Chair Professorship at NPS for the purpose of providing students with industry expertise that is not readily available on campus.

For many years NPS has sponsored ongoing research in various space-related fields. LM-MSO has long provided industry's in-depth technical support to numerous government agencies. LM-MSO will provide a part-time Chair Professor at NPS, thus providing industry support to NPS's academic and technical objectives. NPS clearly recognizes the advantage to its students with such an industry partnership. Sponsorship of this Chair Professorship is consistent with NPS goals to foster innovative research and to work more closely with its mission partners in the military services, academia, and industry.

Duties of the Chair will include, but are not limited to, presenting seminars at NPS and also arranging for seminars and guest speakers to provide technical expertise in technical areas of interest to NPS. The Chair Professor will identify and coordinate LM-MSO technical experts to provide support for students for specific technologies as agreed to by NPS and LM-MSO.

The first incumbent of the LM-MSO Chair Professorship is **Dr. Jerry Zakrzewski**. Dr. Zakrzewski received his Ph.D. from the University of Washington and has over 32 years of professional experience, including 22 years of satellite program development and technical support at LM-MSO. His primary responsibilities at LM-MSO include technology development of advanced composites and new materials as well as major program support for development of dimensionally stable structures. He has also worked in the development of composite microwave components including metallized microwave filters, waveguides, lens antennas, and feed horns.

JOINT DEFENSE TECHNOLOGY AND SYSTEMS CURRICULUM, *continued from page 21*

Initially, two faculty from NPS will teach at NUS for portions of the first two quarters. NUS will then provide two faculty at NPS for the following year. It is expected that NUS and NPS faculty will participate in some joint research and joint supervision of student theses. All the students are scheduled to participate in the highly interdisciplinary systems engineering project focused on future military capabilities and guided by the distinguished Board of Advisors of the NPS Institute for Defense Systems Engineering and Analysis.

The program is a challenging, intense and nontraditional curriculum, which provides a solid understanding of the principles and applications of industrial and technology engineering, and employs these principles to gain insight into operational problems in warfighting systems. Additionally, the program will provide both students and faculty with a learning and research environment steeped in experimenting and doing, while creating bonds among the U.S. and international students and faculty from the operational, scientific, technological, and defence industry communities.

NAVAL POSTGRADUATE SCHOOL AND PEARSON PEACEKEEPING CENTRE ENTER INTO STATEMENT OF INTENT

The Pearson Peacekeeping Centre (PPC) was established by the Government of Canada to support and enhance the Canadian contribution to international peace, security and stability. The PPC fulfills its mandate by conducting research, training and education in all aspects of modern peacekeeping. As part of its business plan and operational approach, the PPC seeks opportunities to cooperate and collaborate with like-minded institutions.

The Statement of Intent details the conditions under which the PPC will provide elements of its peacekeeping simulation methodology to NPS, at no cost to NPS. The PPC has developed a simulation system named *Orion* designed to support a wide range of exercises with a peace operations theme. Currently *Orion* supports three major general scenarios, known as streams. These are:

- United Nations (UN) Strategic and Theatre Level Integrated Mission Stream (Ex C99)
- UN Strategic and Theatre Level Military HQ Stream (Ex Toro Azul) (designed for command and staff colleges)
- NATO Theatre Level Military HQ Stream (Ex Exploring Sword)(designed for a Three Star military headquarters).

MEMORANDUM OF AGREEMENT SIGNED BETWEEN THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION DRYDEN FLIGHT RESEARCH CENTER AND THE NAVAL POSTGRADUATE SCHOOL

This Memorandum of Agreement (MOA) establishes a basis for cooperative research efforts between the National Aeronautics and Space Administration Dryden Flight Research Center (NASA Dryden) and the Naval Postgraduate School/ Center for Interdisciplinary Remotely Piloted Aircraft Studies (NPS/CIRPAS). The purpose is to utilize the technology development, flight experiments and demonstrations, and payloads development and integration for advanced remotely piloted aircraft (RPA) for the development and execution of educational outreach and public awareness programs in support of communicating the knowledge of these agencies to the general public. This agreement will promote effective technology transfer and outreach collaboration between NASA, the Office of Naval Research, and NPS/CIRPAS

NASA's Environmental Research Aircraft & Sensor Technology (ERAST) Program demonstrated the use of RPAs for cost effective science missions and provided the impetus for this activity. Flight demonstration programs and science missions were identified as examples and were used as baselines for the development of educational and public awareness programs and technology transfer activities. The solar-powered Pathfinder aircraft was a major success which generated educational materials and demonstrated the possible civil/commercial use of these aircraft. The Public Affairs, Commercialization and Education (PACE) Office located at the NASA Dryden will be the lead organization to continue the collaboration between NASA and CIRPAS in the development and demonstration of outreach programs that will leverage on the past and current NASA RPA and Airborne Science programs.

The Office of Naval Research (ONR), Naval Postgraduate School (NPS) and the California Institute of Technology (CIT) developed a research facility known as the Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS). The research facility provides new capabilities for atmospheric and oceanographic measurements. The Center's charter is to provide low-cost air vehicle platforms for research and technology purposes and to support the graduate education mission of NPS.

NAVAL POSTGRADUATE SCHOOL AND THE UNIVERSITY OF CENTRAL FLORIDA ENTER INTO EDUCATION AND RESEARCH PARTNERSHIP AGREEMENT

Based on the capabilities of the partners, the Naval Postgraduate School and the University of Central Florida have entered into an Education and Research Partnership Agreement.

The Department of the Navy established the Naval Postgraduate School to meet its educational requirements through the use of specially tailored academic programs and a distinctive organization tying academic disciplines to naval and joint military applications. The University of Central Florida (UCF) is a comprehensive state university that values academic excellence and the integration of learning, working, and residential living with a multicultural and interdisciplinary community.

This educational partnership agreement promotes joint educational and professional projects for each participants mutual advantage. The partnership will also forge a cooperative relationship to further the educational, research and service missions of each partner. The purpose of this partnership is to encourage and enhance Distributed Learning (DL) education and research opportunities by combining the capabilities and resources of the partners. The partners will take steps to encourage formal and informal working relationships of mutual benefit.

COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENT BETWEEN THE NAVAL POSTGRADUATE SCHOOL AND SBC TECHNOLOGY RESOURCES INC. FOCUSES ON QUALITY OF SERVICE MANAGEMENT

The Naval Postgraduate School and SBC Technology Resources Inc. have entered into a Cooperative Research and Development Agreement (CRADA) to develop a better understanding of how the behavior of two main types of networking nodes, the edge nodes and tandem nodes, could be improved based on the presence of intelligent agents at different observation points within the network. The specific research task is to identify the feedback mechanisms capable of utilizing information gathered by intelligent agents for optimizing network resources usage. The study will focus on the experimental research based on testing and proof-of-concept experiments. The research should provide an experimental background for addressing the problems of networking resources adaptation in Quality of Service Management.

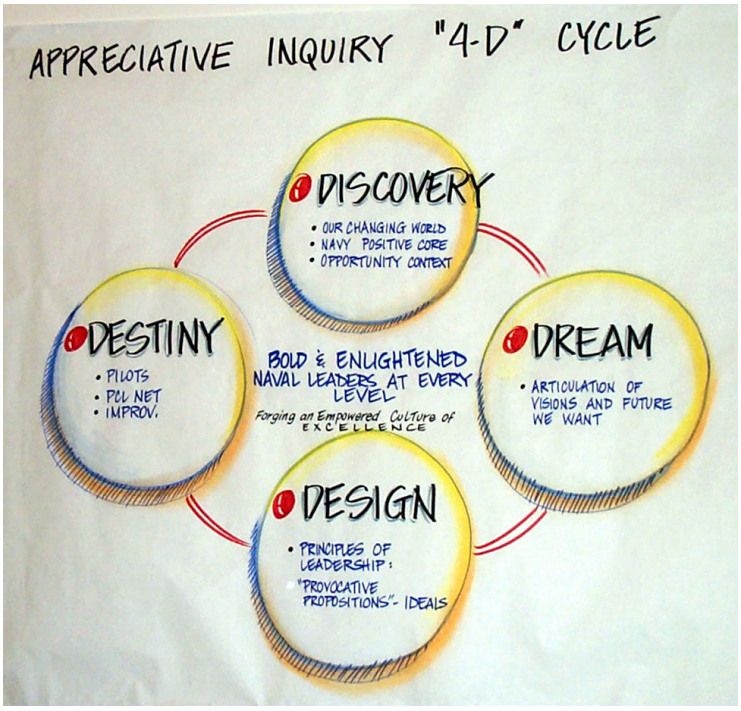
THE LEADERSHIP SUMMIT: Bold and Enlightened Naval Leaders at Every Level Forging an Empowered Culture of Excellence

The Leadership Summit was held at the Naval Postgraduate School 3-6 December 2001. The first of its kind, the Summit assembled over 260 people ranging from Seaman to Admiral, that also represented all backgrounds in our Navy. The Leadership Summit was an application of a new way to view and lead large-scale change called a Large Group Intervention (LGI). Combining LGIs with the positive change approach of Appreciative Inquiry yielded a dynamic summit process for rapid, collaborative change. Hence, the Leadership Summit was aimed at leadership improvement and our Navy's system of leadership development, utilizing an LGI with Appreciative Inquiry to quickly get to decision points with input from all stakeholders.

During the Leadership Summit, participants used Appreciative Inquiry questions to tap into their own past high-point experiences in the Navy. The diverse group present discovered many commonalties and hopes for the future. The participants then learned how to leverage these past strengths and shared visions to create action plans for positive change.

Specific outcomes included over 30 pilot projects. Additionally, the Leadership Summit:

- Created a shared vision and alignment for the kind of leadership the Navy is calling for in its future
- Provided spark for Task Force EXCEL's leadership component
- Established a method to collect examples of exemplary leadership
- Focused on the importance of positive "self-talk" and Appreciative Inquiry as a tool for leaders



- Empowered participants with the knowledge of Appreciative Inquiry and the summit method
- Demonstrated the value of this methodology for other complex issues facing the Navy
- Provided participants a heightened sense of the possibilities ahead; a positive effect on retention.

The Leadership Summit initiative was briefed to the Chief of Naval Operations in October 2000. Admiral Clark has since championed the effort as a CNO pilot project, and participated in the Summit on the third and fourth days. Additional information about the Leadership Summit can be found at http://www.cee.nps.navy.mil/NewSite/leadership_summit.htm.

In January 2000, the Honorable Jerry Hultin, then Under Secretary of the Navy, convened 19 mid-grade officers at the Center for Executive Education at the Naval Postgraduate School in Monterey, California. The course was called "30-Something" and was a seminal innovation by senior leadership to tap the ideas of mid-level Navy executives. The group was given free rein to envision their Navy/Marine Corps of 2020. While many ideas were developed the group focused around their core vision of a Navy/Marine Corps that could "attract and retain great people." A central part of this goal was leadership.

High quality leadership is a cornerstone for everything our Navy does. As the 21st Century, Information Age Navy takes shape, how will leadership need to adapt? Today's rapid pace of change and increasing uncertainty is fueled by the constant development of new information technologies. This forces our Navy to become more adaptable, faster, and flexible in response. Growing access to information will increase participation in decision-making processes. Hence, our people must be ready to respond, in kind, by stepping up to the call for increased responsibility and leadership. Further, the changing values of the Internet generation are an important consideration for all leaders

CONFERENCES

WORKSHOP ON BIOCOMPLEXITY IN THE ARCTIC ENVIRONMENT

Research Associate Professor Wieslaw Maslowski of the Department of Oceanography, along with scientists from Woods Hole Oceanographic Institution (WHOI) and the National Oceanographic and Atmospheric Administration (NOAA), hosted a 2-day interdisciplinary workshop at NPS in November. The purpose of the workshop was to examine the effects of changing environmental conditions and increased human activities on marine mammal abundance and Native subsistence harvests in the western Arctic Ocean. This National Science Foundation (NSF)-sponsored meeting was attended by researchers from Oregon State University (OSU), University of Rhode Island (URI), University of Alaska Fairbanks (UAF), Alaska North Slope Borough, WHOI, and NOAA.

The main theme of the discussions was the complex suite of human-environment-whale interactions along the shelf and slope of the Beaufort Sea. The workshop focused on determining ways to quantify linkages among physical (i.e. large scale wind patterns, ice extent, water mass distribution and mixing) and biological (i.e. nutrient concentration, primary and secondary productivity) conditions, commercial explorations (e.g. off-shore oil and gas development, pollution), whale migration/aggregation patterns and feeding habits, and whale accessibility to the Native subsistence hunters. Understanding of such interactions is especially important in the global warming scenario, which is predicted to result in at least a partially ice-free Arctic Ocean.

The Arctic Ocean has been warming during the last decade (as compared to the long-term mean conditions), causing a thinning of the ice and a decrease of the overall area. This has been reported in both the scientific literature and the public media and is based on observations from submarine and icebreaker expeditions during the 1990s. Should the Arctic Ocean continue to warm and the sea ice melt significantly, it will allow the use of the northern route from Japan and other countries in Asia through Bering Strait to Europe as an alternative and shorter shipping route compared to the one through the Panama Canal. Consequently, an increase in commercial activities in the Arctic Ocean would not only require a better understanding of their influence on the regional environment and ecosystem but it will also change the strategic importance of this region. This means that environmental studies of the Arctic Ocean might soon become a high priority for the U.S. Navy also.

TECHNOLOGY REVIEW AND UPDATE: A SHORT COURSE FOR TECHNICAL PERSONNEL AND DECISION MAKERS

The 19th Annual Technology Review and Update Short Course will be held at NPS the week of 22-26 April 2002. The success and popularity of this short course is ensured by recruiting outstanding experts from industry, academia and the government and by constantly fine tuning the contents. The course is intended for military and civilian technical personnel and decision-makers that need to refresh and update their technical knowledge. The course provides an excellent overview of key technologies, stressing practical aspects and providing insight into trends. An overview of this year's program is provided below:

Internet Security: Opportunity or Oxymoron
- The Problem: Threats and Vulnerabilities
- Internet Components of Consequence
- Electronic Commerce: Where Security Matters
- Cyberspace Map and Compass Finding Solutions

Electro-Optical and Infrared Systems
- Laser Designators, Precision-Guided Munitions
- Missile Warning Receivers
- Night Vision and Thermal Imaging
- High Energy Laser Weapon Systems

Optical Sensing Technology
- Overview
- Fiber-optic Technology Relevant to Sensors
- State of the Art of Optical Sensors
- Case Studies of Optical Sensors

Micro-Electro-Mechanical Systems (MEMS)
- Introduction to MEMS
- Physical Principles for Sensing and Actuation
- Processing Silicon for Use in MEMS
- MEMS Examples: Past, Present and Future

Integrated Circuits
- Introduction to Analog and Digital Integrated Circuits
- High Speed Electronic Systems Design

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MILITARY EQUIPMENT PARAMETRICS AND ENGINEERING DATABASE (MEPED) USERS CONFERENCE AND TECHNICAL WORKING GROUP

The Military Equipment Parametrics and Engineering Database (MEPED) Users Group, the MEPED Team, and representatives from the Defense Intelligence Community will hold their annual MEPED Users Conference and Technical Working Group on 26-28 March 2002 at the Naval Postgraduate (NPS). The purpose of this conference is to provide users with an update on the execution of their existing requirements and to solicit new requirements. This will be the first time this annual conference has been held at the NPS.

MEPED is a DIA Intelligence Mission Application (IMA). It is a collaborative effort by DIA and the Defense Intelligence Production Centers to provide users high quality, responsive, and "Pull" access to Department of Defense Intelligence Production Program (DoDIPP) validated characteristics and performance (C&P) data on foreign weapon systems. MEPED, a distributed database, is the DoDIPP means for providing Warfighters and Force Developers with online access to the disparate C&P databases at the Defense Intelligence Production Centers. The Defense Intelligence Production Centers that are responsible for populating and maintaining data in MEPED are DIA Missile and Space Intelligence Center, National Air Intelligence Center, National Ground Intelligence Center, Office of Naval Intelligence, and Marine Corps Intelligence Activity.

For additional information contact **Ms. Rita Painter** at rpainte@nps.navy.mil.

TECHNOLOGY REVIEW AND UPDATE,

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- Programmable Logic
- The Future of Integrated Circuits

Bioengineering and Biotechnology
- Biomedical Sensors and BioMEMS
- Biotechnology, Genomics, and Proteomics
- Biomaterials and Tissue Engineering
- Bioinformatics and Biological Warfare Agents

Military Satellite Communications Technology
- Introduction to Military Satellites Communications and Network-Centric Warfare
- Present and Future Narrow-band and Wide-band Satellite Communications
- Present and Future Protected Satellite Communications
- Military Use of Commercial Satellite Communications Systems

Satellite Communication Technologies and Trends
- The Satellite Communications Revolution
- GEOs, MEOs and LEOs on the Horizon
- Key Drivers and Enabling Technologies
- Next Generation Satellite Communications Systems

Registration information can be found on line at http://www.sp.nps.navy.mil/trau.

PACIFIC LANDFALLING JETS EXPERIMENT (PACJET) WORKSHOP

The Pacific Landfalling Jets Experiment (PACJET) 2001 Workshop was held at the Naval Postgraduate School (NPS) this past October to summarize experiences from the field program of January and February 2001. Nearly 70 participants attended the three day workshop representing such diverse organizations as the Navy (NPS, Naval Research Laboratory, Fleet Numerical Meteorology and Oceanography Center), Pacific Gas &Electric, the Port of Long Beach, universities, the National Weather Service and various National Oceanographic Atmospheric Agency research laboratories and institutions. The purpose of the workshop was to explore methodologies to improve how future PACJET field programs can better meet the needs of the operational forecast community and civilian commercial and emergency entities, while also providing critical observations to research scientists for improving their understanding of the structure and evolution of storms along the west coast of the United States. This years scaled-down PACJET field program will be based out of Portland, Oregon, and will focus on verifying satellite algorithms over the open ocean as well as to observe surface fluxes of heat over the ocean in order to evaluate their role in conditioning the environment for subsequent storm development.

For additional information on the PACJET program, contact **Research Assistant Professor Doug Miller**, Department of Meteorology, at dkmiller@nps.navy.mil.

FACULTY NEWS

GRADUATE SCHOOL OF BUSINESS AND PUBLIC POLICY

D.N. Fowler and **M.E. Nissen**, "Innovating the Federal Acquisition Process through Intelligent Agents," *Acquisition Review Quarterly*, 8:3, pp. 151-165, 2001.

G. Fann-Thomas, "Using Discourse Analysis to Explore Business and Managerial Communication," Association for Business Communication Annual Convention, San Diego, CA, 7-10 November 2001.

W.R. Gates and **M.E. Nissen**, "An Empirical Investigation of e-Employment Market Designs," *Proceedings of the International Conference on Electronic Commerce Research*, Dallas, TX, November 2001.

K.R. Gue and **K. Kang**, "Staging Queues in Material Handling and Transportation Systems," *Proceedings of the 2001 Winter Simulation Conference*, 2001.

D. Henderson, "The Joy of Freedom: An Economists Odyssey," *Financial Times,* Prentice Hall, 2001.

I. Lewis, "Logistics and Electronic Commerce: An Inter-Organizational Systems Perspective," *Transportation Journal*, 40(4), 5-13, Summer 2001.

I. Lewis and A. Talalayevsky, "Automobile Retailing: Will the Internet Support New Channels or Intermediaries?" Annual Meeting of the Decision Sciences Institute, San Francisco, CA, 18 November 2001.

S. Mehay and Barry Hirsch, "An Evaluation of the Labor Market Experiences of Veterans Using a Matched Comparison Group Design," Annual Meetings of the Southern Economic Association, Tampa, FL, 19 November 2001.

M.E. Nissen, "BPR Conceptual Modeling," Bureau of Naval Personnel CIO, Millington, TN, December 2001.

Distinguished Emeritus Professor Robert E. Ball received the National Defense Industrial Association (NDIA) Combat Survivability Award for Lifetime Achievement. The world pioneer in aeronautics and the father of aircraft survivability education accepted the honor during the professional association's symposium on Integrating Survivability into 21st Century (Aircraft) Designs. Joining the NPS faculty in 1967, Professor Ball has educated over 3,500 NPS officer students from all U.S. military services, DoD acquisition professionals, members of NATO allies, and industry representatives. In 1977, he developed the first combat survivability course ever offered at an educational institution as part of the regular curriculum at NPS, and in 1985, published what is still the only textbook on all aspects of aircraft survivability, *The Fundamentals of Aircraft Combat Survivability Analysis and Design*. The American Institute of Aeronautics and Astronautics will publish an updated and significantly expanded second edition of the book in 2002.

M.E. Nissen, "Measurement-Driven Enterprise Systems Engineering," *Journal of Engineering Valuation and Cost Analysis*, 4:1, pp. 63-76, 2001.

J. San Miguel, "Emerson Electric Company and Dallas Consulting Group," *Cost-Management: A Strategic Emphasis-Cases and Readings*, E.J. Blocher, K.H. Chen, and T.W. Lin, eds., 2nd Ed., McGraw-Hill/Irwin, 2002.

J. Suchan and M. Komar, "Communication Processes and Norms in an Asynchronous Distance Learning Course," Association for Business Communication Annual Convention, San Diego, CA, 7-10 November 2001.

G. Thomas, "Raising the Bar-Embracing Managing Diversity and Inclusion," Navy's Equal Opportunity Advisors Symposium, Millington, TN, 27 November 2001.

K.W. Thomas, "Collaborating and the Conflict-Handling Modes," Colorado Issues Network and Associated Consultants International, Denver, CO, 7-8 September 2001.

K.W. Thomas, "Exploring a Three-Dimensional Model of Leadership," Colorado Issues Network and Associated Consultants International, Denver, CO, 7-8 September 2001.

K.W. Thomas, "Intrinsic Motivation," Colorado Issues Network and Associated Consultants International, Denver, CO, 7-8 September 2001.

K.W. Thomas and W.G. Tymon, Jr., "Intrinsic Motivation: Being Energized in Your Work," Analytical Laboratory Managers Association, Keemah, TX, 2 November 2001.

GRADUATE SCHOOL OF ENGINEERING AND APPLIED SCIENCES

Aeronautics and Astronautics

C. Brophy, **J. Sinibaldi**, and **P. Damphousse**, "Initiator Performance for Liquid Fueled Pulse Detonation Engines," American Institute of Aeronautics and Astronautics Aerospace Sciences Meeting, Reno, NV, 18 January 2002.

J.C.S. Lai, J. Yue, and **M.F. Platzer**, "Control of Backward-Facing Step Flow Using a Flapping Foil," *Experiments in Fluids*, Vol. 32, Issue 1, pp. 44-54, 2002.

K.D. Jones, **B.M. Castro**, **O. Mahmoud**, and **M.F. Platzer**, "A Numerical and Experimental Investigation of Flapping Wing Propulsion in Ground Effect," American Institute of Aeronautics and Astronautics Paper, 2002-0866, 40th Aerospace Sciences

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Meeting, Reno, NV, 14-17 January 2002.

K.D. Jones, **B.M. Castro**, **O. Mahmoud**, S.J. Pollard, **M.F. Platzer**, M.F. Neef, K. Gonet, and D. Hummel, "A Collaborative Numerical and Experimental Investigation of Flapping Wing Propulsion," American Institute of Aeronautics and Astronautics Paper 2002-0706, 40th Aerospace Sciences Meeting, Reno, NV, 14-17 January 2002.

K.D. Jones, T.C. Lund, and **M.F. Platzer**, "Experimental and Computational Investigation of Flapping Wing Propulsion for Micro Air Vehicles," *Progress in Astronautics and Aeronautics, Fixed and Flapping Wing Aerodynamics for Micro Air Vehicle Application*, Vol. 195, American Institute of Aeronautics and Astronautics, pp. 307-339, 2002.

S. Searles, **C. Brophy**, and **J. Sinibaldi**, "Soot Production Characteristics for JP-8, JP-8+100, and JP-10," JANNAF Exhaust Plume Technical Subcommittee Meeting, San Antonio, TX, November 2001.

S. Weber, **K.D. Jones**, J.A. Ekaterinaris, and **M.F. Platzer**, "Transonic Flutter Computations for the NLR 7301 Supercritical Airfoil," *Aerospace Science and Technology*, Vol. 5, pp. 293-306, 2001.

Electrical and Computer Engineering

E.R. Bachmann, **R.B. McGhee**, **X. Yun**, and **M. Zyda**, "Inertial and Magnetic Posture Tracking for Inserting Humans into Networked Virtual Environments," *Proceedings of the ACM Symposium on Virtual Reality Software and Technology (VRST 2001)*, Banff, Alberta, Canada, 15-17 November 2001.

Prof. J.T. Butler is a co-recipient of the Takeda Techno-Entrepreneurship Award from the Takeda Foundation. This is in support of the research project, "On New Types of Programmable Logic Devices and Their Logic Synthesis." Jon Butler is part of a team composed of researchers from Kyushu Institute of Technology, Portland State University and the Naval Postgraduate School. An award ceremony was held in Tokyo, Japan, 4 December 2001.

R. Hippenstiel, *Detection Theory: Applications and Digital Signal Processing*, CRC Press, December 2001.

R.W. Ives, "Near Lossless Compression of SAR Imagery Using Gradient Adaptive Lattice Filters," 35th Asilomar Conference on Signals, Systems and Computers, Monterey, CA, November 2001.

J.L. Marins, **X. Yun**, **E.R. Bachmann**, **R.B. McGhee**, and **M. Zyda**, "An Extended Kalman Filter for Quaternion-Based Orientation Estimation Using MARG Sensors," *Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2001)*, Maui, HI, 29 October-3 November 2001.

P.E. Pace, "Adaptive Power-Managed FMCW Emitter Detection Performance Against Low-RCS Ships," *Proceedings of the 35th Asilomar Conference on Signals, Systems and Computers*, MP8B, 4 November 2001.

P.E. Pace, D. Wickersham, **D. Jenn**, and N.S. York, "High Resolution Phase-Sampled Interferometry Using Symmetrical Number System," *IEEE Transactions on Antennas and Propagation*, Vol. 49, No. 10, pp. 1411-1423, October 2001.

X. Yun, **E.R. Bachmann**, S. Arsian, and K. Akyol, "An Inertial Navigation System for Small Autonomous Underwater Vehicles," *Advanced Robotics*, Vol. 15, No. 5, pp. 521-532, October 2001.

Mechanical Engineering

T. Sarpkaya, "Hydrodynamic Damping and Quasi-Coherent Structures at Large Stokes Numbers," *Journal of Fluids and Structures*, Vol. 15, No. 7, pp. 909-928, 2001.

Meteorology

K.L. Davidson and **P.A. Frederickson**, "Mid-Path Near-Surface Atmosphere Properties in Roughness and Evaporation Duct (RED) Experiment," Boulder, CO, 9-12 January 2002.

P.A. Frederickson and **K.L. Davidson**, J. Stapleton, D. Shanklin, R. Wiss, T. Nguyen, E. Burgess, C. Weeks, W. Thornton, and T. Brown, "Evaluation of Evaporation Duct Model Performance Using AREPS," National Audio Science Meeting, Boulder, CO, 9-12 January 2002.

P.S. Guest, **K.L. Davidson**, **P.A. Frederickson**, and D. Mabey, "Using Instrumented Kites to Quantify Atmospheric Conditions During the Roughness and Evaporation Duct (RED)

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NASA has selected nine research proposals for negotiation of Phase 2 contract awards for its 2000 Small Business Technology Transfer (STTR) Program. Phase 2 continues development of the most promising previously selected Phase 1 projects. Selection criteria include scientific and technical merit, future importance and eventual value of the innovation to NASA, company capabilities and commercial potential. **Research Assistant Professor Ramesh Kolar** is the "research institution" partner with Scientific Systems Company, Inc. on a project titled "Integrated Software Toolbox for Aeroelastic Modeling and Dynamic Stability Analysis of Air Vehicles," and with Stirling Dynamics, Inc. on a project titled, "Finite Element Multi-Disciplinary Analysis of Flight Vehicles."

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Experiment," National Audio Science Meeting, Boulder, CO, 9-12 January 2002.

Oceanography

P.C. Chu, "Toward Accurate Coastal Ocean Prediction," *Advances in Mathematical Modeling of Atmosphere and Ocean Dynamics*, P.E. Hodnett, ed., Kluwer Scientific Publishing Co., pp. 131-136, 2001.

P.C. Chu and **C.W. Fan**, "A Low Salinity Cool-Core Cyclonic Eddy Detected Northwest of Luzon During the South China Sea Monsoon Experiment (SCSMEX) in July 1998," *Journal of Oceanography*, 57, pp. 549-563, 2001.

P.C. Chu and **C.W. Fan**, "An Accuracy Progressive Sixth-Order Finite Difference Scheme," *Journal of Atmospheric and Oceanic Technology*, 18, pp. 1245-1257, 2001.

P.C. Chu, J. Lan, and **C.W. Fan**, Japan/East Sea (JES) Circulation and Thermohaline Structure, Part 1, Climatology, *Journal of Physical Oceanography*, 31, pp. 244-271, 2001.

P.C. Chu, J. Lan, and **C.W. Fan**, "Japan/East Sea (JES) Circulation and Thermohaline Structure, Part 2, A Variational P-Vector Method," *Journal of Physical Oceanography*, 31, pp. 2886-2902, 2001.

P.C. Chu, S.H. Lu, and **C.W. Fan**, "An Air-Ocean Coupled Nowcast/Forecast System for the East Asian Marginal Seas," *Advances in Mathematical Modeling of Atmosphere and Ocean*, P.E. Hodnett ed., Kluwer Scientific Publishing Co., pp. 137-142, 2001.

P.C. Chu, S.H. Lu, and **Y.C. Chen**, "Evaluation of the Princeton Ocean Model Using the South China Sea Monsoon Experiment 9SCSMEX) Data," *Journal of Atmospheric and Oceanic Technology*, 18, pp. 1245-1257, 2001.

A patent was issued to **Research Professor Timothy Stanton**. The patent titled, "Turbulence-Resolving Coherent Acoustic Sediment Flux Probe Device and Method" (US 6,262,942), describes a new method to estimate the sediment flux in front of a Coherent Acoustic Sediment Probe (CASP) instrument. Also described is a newly invented Bistatic Doppler Velocity and Sediment Profiler (BDVSP) device for measuring sediment concentration, sediment velocity, and the resultant sediment transport in a sediment bed, and for the measurement of turbulent stresses and dissipation in the ocean.

P.C. Chu, X.S. Chen, and **C.W. Fan**, "Comparison Between Wavenumber Truncation and Horizontal Diffusion Methods in Spectral Models," *Monthly Weather Review*, 129, pp. 152-158, 2001.

P.C. Chu, **Y.C. Chen**, and S.H. Lu, "Evaluation of Haney-Type Surface Thermal Boundary Condition Using a Coupled Atmosphere and Ocean Model," *Advances in Atmospheric Sciences*, 18, pp. 355-375, 2001.

Q. Liu, Y. Jia, P. Liu, **Q. Wang**, and **P.C. Chu**, "Seasonal and Intraseasonal Thermocline Variability in the Central South China Sea," *Geophysical Research Letter*, 2001.

P. Luong, C.P. Breshears, and **L.N. Ly**, "Coastal Ocean Modeling of the U.S. West Coast with Multi-Block Grid and Dual-Level Parallelism," *ACM/IEEE SC2001 Conference Proceedings*, Seoul, Korea, September 2001.

Professor N.F. Schneidewind received the IEEE Reliability Engineer of the Year 2001 award from the IEEE Reliability Society. The award is in recognition of his contributions to Software Reliability Modeling and Reliability Leadership of key national purpose programs, such as the Space Shuttle Program.

P. Luong, **L.N. Ly**, C.P. Breshears, "Comparison of Multi-Block Grid and Domain Decomposition in Coastal Ocean Modeling," HPC User Group Conference, Biloxi, MS, 12-14 June 2001.

L.N. Ly, "Circulation-Wave Coupling with a Surface Wave Parameterization, 5th IOC/WESTPAC Conference," Seoul, Korea, 27-31 August 2001.

L.N. Ly, "Development of a Coupled Circulation-Wave Model with a Surface Wave Parameterization," Multi-Physics Couplings for Geosciences, 6th SIAM Conference on Mathematical and Computational Issues in the Geosciences, Boulder, CO, 11-14 June 2001.

Prof. L.N. Ly was invited to co-chair the Ocean Dynamics and Climate section of the 5th Inter-governmental Oceanographic Commission (IOC)/West Pacific (WESTPAC) International Scientific Symposium, Seoul, Korea, 27-31 August 2001.

L.N. Ly and **C. Collins**, "Circulation-Wave Coupling with a Surface Wave Parameterization for the Idealized California Coastal Region," *4th Conference on Coastal Atmospheric and Oceanic Prediction Proceedings*, St. Petersburg, FL, November 2001.

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GRADUATE SCHOOL OF OPERATIONAL AND INFORMATION SCIENCES

Computer Science

N.C. Rowe, "Finding and Labeling the Subject of a Captioned Depictive Photograph," *ACM Transactions of Knowledge and Data Engineering*, January-February 2002.

Information Sciences

T. Housel, "Measuring the Return on Information Technology Embedded in Organizational Processes," International Conference on Information Systems, New Orleans, LA, 17 December 2001.

G. Zolla, T. Boex, P. Flanders, D. Nelson, S. Tufts, and **J.K. Schmidt**, "Distributed Maintenance Error Information, Investigation, and Intervention," World Aviation Congress & Exposition, Seattle, WA, 2001.

Operations Research

S.E. Buttrey, **D. Nolan**, and D. Temple Lang, "Computing in the Mathematical Statistics Course," *Proceedings of the American Statistics Association 2001 Annual Meeting*.

R. Looney, **D. Schrady**, and R. Brown, "Estimating the Economic Benefits of Forward-Engaged Naval Forces," *INTERFACES*, Vol. 31, No. 4, July-August 2001.

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A. Marin and **J. Salmeron**, "A Risk Function for the Stochastic Modeling of Electric Capacity Expansion," *Naval Research Logistics*, Vol. 48, pp. 662-683, 2001.

D. Morton, **J. Salmeron**, and **K. Wood**, "Optimizing Military Sealift Subject to Attack," INFORMS, Miami Beach, FL, November 2001.

S.M. Sanchez, "ABCs of Output Analysis," *Proceedings of the 2001 Simulation Conference*, B.A. Peters, J.S. Smith, D.J. Medeiros, and M.W. Rohrer, eds., Piscataway, NJ, 2001.

Prof. S.M. Sanchez was appointed Deputy Editor of *Naval Logistics*, January 2002.

S.M. Sanchez and G. Hynes, "Assessment and Perception of On-Line Communication Skill Acquisition," Symposium on Assessing the Quality of On-Line Instruction, Monterey, CA, 23-25-October 2001.

K. Wood and **S.M. Sanchez**, "Solving Stochastic Network Interdiction with the BEST Algorithm," AFOSR PI Meeting, Minnowbrook, NY, 2001.

K. Wood and **S.M. Sanchez**, "Solving Stochastic Network Interdiction with the BEST Algorithm," Mathematics Department Seminar, Davis, CA, 5 October 2001.

SCHOOL OF INTERNATIONAL GRADUATE STUDIES

Defense Resources Management Institute

D.I. Angelis, "An Option Model for R&D Valuation," *International Journal of Technology Management*, 2001.

Prof. D.I. Angelis completed the first phase of a study on Cost Information Needs of Project Managers. The study is sponsored by the Cost-Management Systems Program of CAM-I.

P.C. Frederiksen and **R. McNab**, "The Relationship Between Defense Spending and Economic Growth: A Granger Causality Analysis for Malaysia," 1961 to 1999, *STRATEGI*: *Journal of Strategic Studies and International Relations*, January 2002.

R. McNab and J. Martinez-Vazquez, "Fiscal Decentralization, Inflation, and Economic Growth," 34th International Public Finance Conference, Cordoba, Argentina, September 2001.

R. McNab and J. Martinez-Vazquez, "Fiscal Decentralization, Macroeconomic Stability, and Growth," Meetings of the National Tax Association, Baltimore, MD, November 2001.

R. McNab and J. Martinez-Vazquez, "Fiscal Decentralization, Macroeconomic Stability, and Growth," Southern Economic Association Meetings, Tampa, FL, November 2001.

N.J. Webb and R. Abzug, "Bad Governance: What are the Costs?" Association for Research on Voluntary and Non-Profit Organizations (ARNOVA) Conference, Miami, FL, 30 November 2001.

THE MODELING, VIRTUAL ENVIRONMENTS, AND SIMULATION (MOVES) INSTITUTE

C. Blais, **D. Brutzman**, **D. Horner**, and **S. Nicklaus**, "Web-Based 3D Technology for Scenario Authoring and Visualization: The SAVAGE Project," 2001 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), Orlando, FL, 25-28 November 2001.

M. Zyda, "Inventing Your Own Academic Degree and Research Institute-The NPS MOVES Program," Herding Cats, Moving Cemeteries, and Hauling Academic Trunks-Managing Change in Higher Education Conference, Los Angeles, CA, 18-19 October 2001.

A QUIET REVOLUTION IN SPACE SYSTEMS, *continued from page 3*

Research Laboratory (AFRL) project lead by Professor Kang, the focus is on the application of the "perceptive frame," a coordinated control framework, to the problem of satellite formation and attitude control (see Figure 3).

Two related problems of formation control, namely the coordination and reconfiguration, are studied in the project. In the theory of perceptive frame, it is assumed that each satellite has its own controller. The perceptive frame is a mathematical model of control architecture to integrate the distributed controllers in a unified framework so that satellites in formation are able to coordinate with each other. The integrated control has the advantage of accommodating a variety of useful coordination strategies such as leader-follower, simultaneous movement, and the combination of different strategies. Changing from one strategy to another is smooth and relatively simple in a perceptive frame. Algorithms of coordinated formation reconfiguration such as satellite re-pointing are also studied in the project. In the presence of disturbances, the relative attitude error of the distributed satellites is significantly reduced using the coordinated controller. In another project lead by Professor Ross, the focus is on the optimal design of the formation configuration. One problem addressed in this project is the design of "invariant relative orbits" which allows the spacecraft to be in formation without the expenditure of any propellant. In reality, some minimal propellant expenditure is needed to account for secular unmodeled disturbances. A simple demonstration of this is evident by comparing Figures 1 and 4. Figure 4 shows the exact same swarm configuration in Figure 1 as designed in terms of "frozen formations." Significantly more complex formations are

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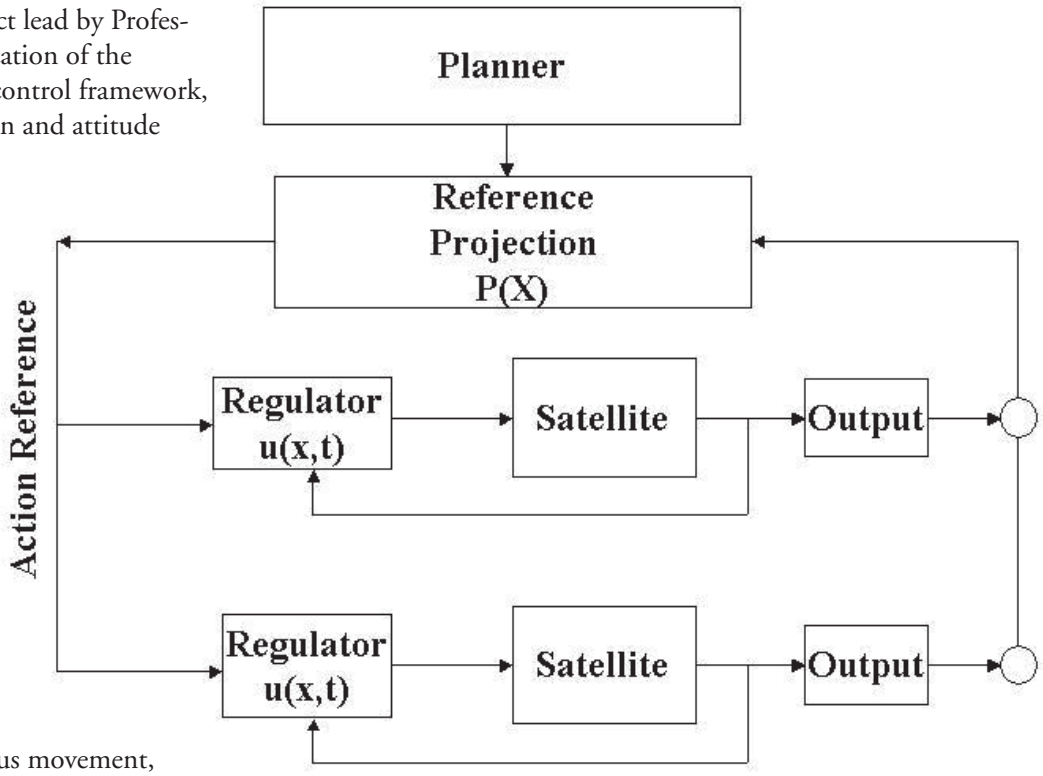

Figure 3. Control Architecture in a Perceptive Frame: Each satellite has a controller u(x,t). The distributed controllers are coordinated through the reference projection P(x), a mathematical model for the management of the real-time sensor information.

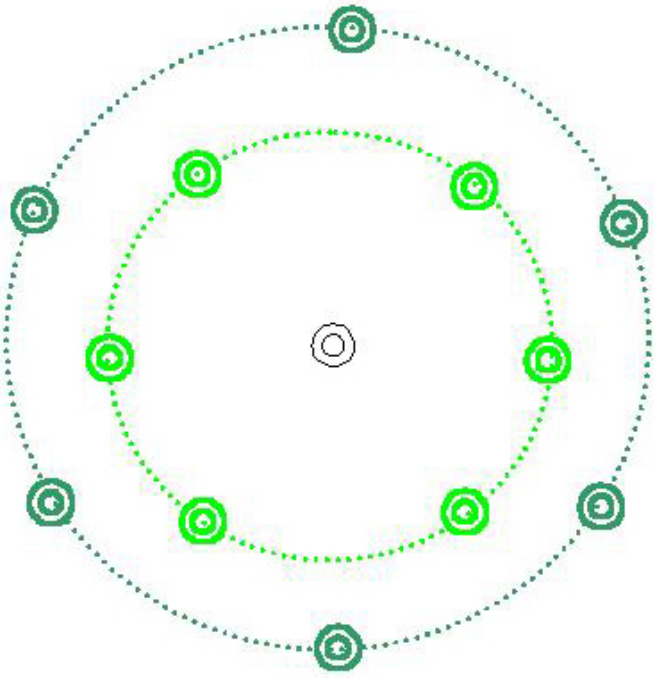

Figure 4. A Simple Demonstration of Satellite Swarm in Relative Invariant Orbits (Compare with Figure 1; this is the exact same configuration). Significantly more complex formations and control techniques are being developed at NPS by Professors Ross, Kang and Fahroo.

A QUIET REVOLUTION IN SPACE SYSTEMS, *continued from page 31*

being designed by Professor Ross and his students. Ross has also developed a mechanism that can achieve precision control at optical and infrared wavelengths without the expenditure of any propellant.

The problem of launching and maneuvering these swarms in a robust and cost effective manner is addressed in a number of projects lead by Professors Ross and Fahroo. The key technology addressed in this area is the real-time computation of optimal controls for nonsmooth nonlinear dynamical systems. Nonsmoothness arises in launch problems as a result of staging, crossing the sound barrier, orbital injection and other phenomena. Nonlinearities are almost everywhere; they are more of a rule than an exception. Instead of smoothing out nonsmoothness and linearizing the nonlinearity – a common practice among many engineers – Professors Fahroo and Ross have developed new efficient methods to not only handle the nonlinearities but, more importantly, to harness them. Their methods have dramatically shortened the distance in achieving the elusive goal of solving these problems in real-time. Real-time solutions to these problems entertain the possibility of a revolutionary approach to guidance, where the guidance laws are no longer pre-computed but solved in an adaptive fashion on an on-board computer. They have encoded some of their ongoing ideas in a reusable software package that is currently being tested by Draper Labs and graduate students at MIT and NPS. Figure 5 is a result from this software applied to what was once considered a difficult problem in low-thrust orbit transfer.

Does this "quiet revolution" in space systems mean that there will not be large flexible spacecraft or massive launch vehicles? Certainly not! It just means that the need for size is significantly less than previously thought. The space station is an example of a large spacecraft. Its need for size is not dictated by aperture requirements but by human habitation. When aperture is the need, it can be argued that large spacecraft are "out," clusters are "in." Ironically, a spin-off of the research by Kang, Fahroo and Ross is that it is now possible to solve the annoying flexibility problem, the bane of large spacecraft.

In a like vein, the need for massive launch vehicles is no longer driven by a single large spacecraft. The ability to do autonomous and semi-autonomous orbital operations (like assembly) obviates the need to launch everything all at once. Streamlined launch vehicles are thus "in"; big clumsy boosters are on their way "out" (see Figure 6). However, it will take a lot longer for the launch

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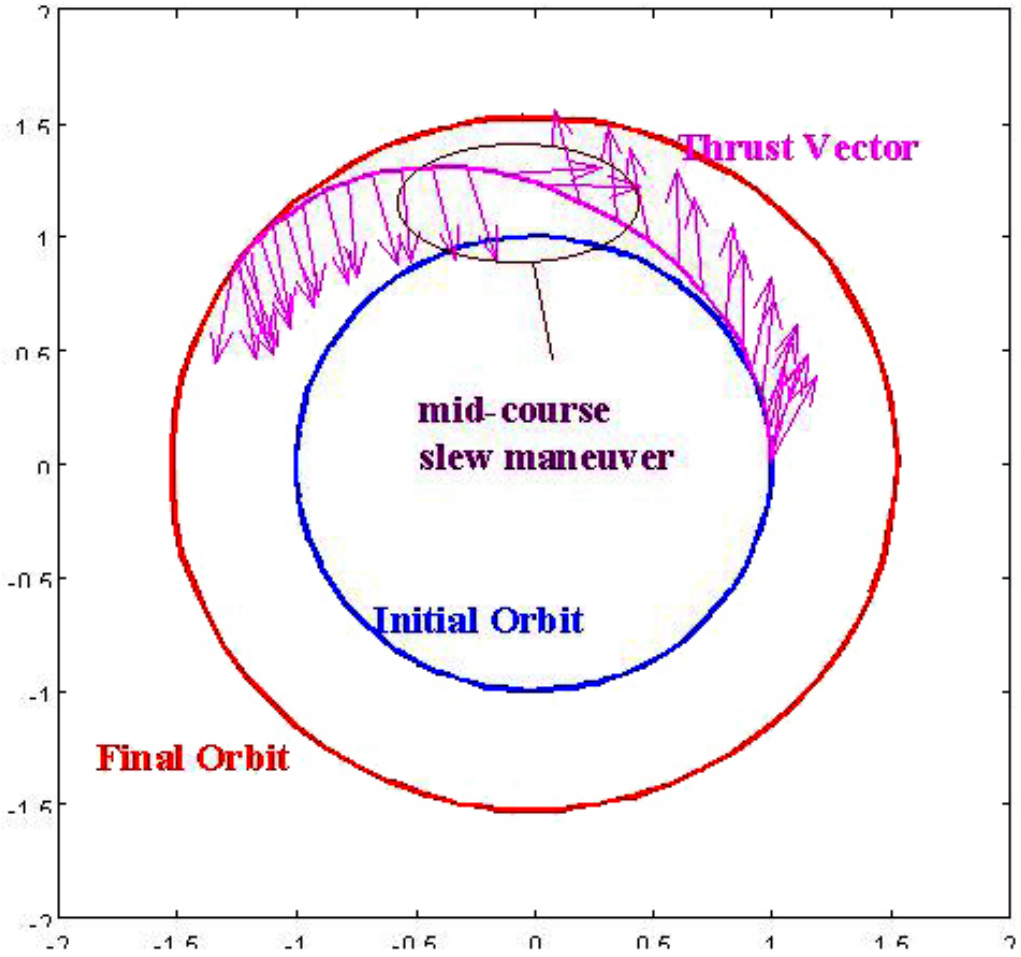


Figure 5. Low-Thrust Orbit Transfer: This once-difficult problem can now be routinely solved by the methods developed by Ross and Fahroo. The thrust vectors are positioned at optimal points known as the Legendre-Gauss-Lobatto points.

A QUIET REVOLUTION IN SPACE SYSTEMS, *continued from page 32*

vehicle industry to change when compared to the rapidly growing acceptance of satellite swarms.

Student thesis work is a significant part of the research described here. In addition to collaborative efforts with MIT students, current NPS graduate students involved in these projects are: **Capt Jon Strizzi, USAF**, pursuing the Ph.D in Astronautics with a minor in Mathematics, **LCDR Robert Stevens, USN**, pursuing an Engineer's degree in Aeronautics and Astronautics, **LT Scott Josselyn, USN**, pursuing an Engineer's degree in Aeronautics and Astronautics, **LT Jeffrey King, USN**, pursuing the M.S. in Astronautics, and **LT James Ross, USN**, pursuing M.S. in Astronautics.

Funding for this research has been provided directly and indirectly by the Air Force Research Laboratory (AFRL), Air Force Space Command, Charles Stark Draper Laboratory, Jet Propulsion Laboratory (JPL), National Aeronautics and Space Administration (NASA), and the Naval Space Command. NPS students have broadened their horizons by spending part of their Experience Tour at these laboratories.

Footnote:

[1] Spacecraft do not fly, they orbit. The term 'flying' is widely used.

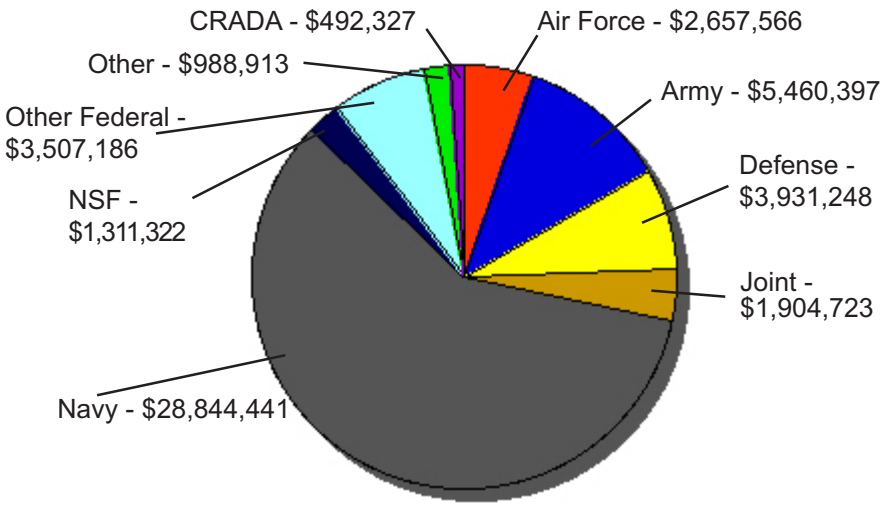
Figure 6. NASA's vision of future reusable launch vehicles (RLVs): The revolutionary space guidance algorithm being developed at NPS in partnership with Draper Labs is one of the common technologies necessary to achieve this vision. Note common features between military and civilian space transportation requirements (courtesy NASA).

RESEARCH STATISTICS

NAVAL POSTGRADUATE SCHOOL'S 2001 SPONSORED PROGRAM

During FY2001, the Naval Postgraduate School's Sponsored Programs exceeded $49 million. Sponsored programs at the Naval Postgraduate School are primarily research (both basic and applied). Sponsored funding is also received for other endeavors including distance learning, course or curriculum development, short courses, mobile education team visits, and conferences. These types of programs constitute approximately 13% of the total sponsored funding executed during FY2001.

Sponsored funding for research and other academic efforts at NPS are funded by the Navy, and other defense, federal, and non-federal agencies. A profile of NPS sponsors is provided below.



FY2001 sponsored research and other academic programs.

NAVY
Office of Naval Research
Naval Air Systems Command
Naval Sea Systems Command
Naval Research Laboratory
Space and Naval Warfare Systems Command
Space and Naval Warfare Systems Center
Naval Air Warfare Centers (Aircraft/Weapons/Training Systems)
Naval Surface Warfare Center (Crane/Dahlgren/Port Hueneme)
Naval Undersea Warfare Center
Naval Engineering Logistics Office/Naval Information Warfare Activity
Chief of Naval Operations
Marine Corps Combat Development Command
Marine Corps Systems Command
Naval Education Training and Security Assistance Field Activity
Chief of Naval Education and Training
CINCPACFLT
Naval Recruiting Command

ARMY
Office of the Assistance Secretary of the Army
U.S. Army Research Office
U.S. Army Tank Automotive Command
U.S. Army Yuma Proving Grounds
U.S. Army Recruiting Command
U.S. Army TRADOC Analysis Command

AIR FORCE
U.S. Air Force Research Laboratory
U.S. Air Force Office of Scientific Research
Secretary of the Air Force
U.S. Air Force Information Warfare Activity
U.S. Air Institute for Advanced Distance Learning

DEFENSE
Defense Advanced Research Projects Agency
Defense Intelligence Agency
Defense Modeling and Simulation Office
Defense Security Cooperation Agency
Defense Threat Reduction Agency
Office of the Secretary of Defense

JOINT
U. S. Joint Forces Command
Joint Staff
Joint Special Operations Command

OTHER FEDERAL
National Aeronautics and Space Administration
National Reconnaissance Office
National Oceanic Atmospheric Agency
Department of Energy
U.S. Coast Guard
National Security Agency
National Science Foundation

OTHER
Industry (Microsoft, Rockwell Science Center, General Electric Aircraft Engines, Hughes Space & Communication, Lockheed-Martin)
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CONFERENCE CALENDAR

UPCOMING CONFERENCES/SHORT COURSES/MEETINGS AT NPS

Date	Title	Sponsor
5-7 Mar 2002	N-912 OPNAV Navy Simulator Validation Working Group	Office of the Chief of Naval Operations and Office of Naval Research
10-15 Mar 2002	Hardened Electronics and Radiation Technology Conference	Defense Threat Reduction Agency, Sandia National Laboratories, and U.S. Army Space & Missile Defense Command Navy Strategic Systems Program Office
26-28 Mar 2002	Military Equipment Parametrics and Engineering Database (MEPED) Users Group Meeting	Defense Intelligence Agency and Naval Postrgraduate School
8-11 Apr 2002	13th Annual U.S. Army Tank-Automotive & Armaments Command (TACOM) Ground Vehicle Survivability Symposium (GVSS)	U.S. Army Tank-Automotive & Armaments Command
18-22 Apr 2002	18th Annual Review of Progress in Applied Computational Electromagnetics	Naval Postgraduate School and Applied Computational Electromagnetics Society
22-25 Apr 2002	5th International Technology and the Mine Problem Symposium	Naval Postgraduate School and Defense Advanced Research Projects Agency
22-26 Apr 2002	19th Annual Technology Review & Update	Naval Postgraduate School
6-9 May 2002	Live Fire Test and Evaluation Conference	National Defense Industrial Association and Defense Advanced Research Projects Agency
5-7 Nov 2002	AIAA Missile Sciences Conference	American Institute of Aeronautics and Astronautics

NPS has excellent facilities for hosting conferences, workshops, symposia, and meetings. The wide range of facilities can accommodate both small and large groups. Additional rooms are available for smaller functions or breakout sessions. Conferences classified through SECRET can be accommodated on the NPS campus. Sensitive Compartmented Information Facility (SCIF) facilities exist and may be available for small groups on a more restricted basis. For more information, contact the NPS Conference Coordinator, Karen Flaherty, at 831-656-2426 or by e-mail, flaherty@nps.navy.mil.

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